SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

ANNUAL CONVENTION NUMBER

Special Features

Effects of Detergents—Manganelli

Surface Tension Measurement—Bowers

Metal Recovery by Ion Exchange—Fadgen

White Water Treatment—Rudolfs and Amberg

Tidal Water Pollution Control—Mills

Twenty-Fifth Annual Meeting—Oct. 6–9, 1952
Hotel Statler, New York City
(See Page 1192)

SEPTEMBER, 1952—VOL. 24, No. 9

Chicago BARMINUTORS

Chicago Pump, the company that developed and perfected the Comminutor, announces the new Chicago Barminutor for plants with flows of 15 MGD and over. Maximum flows of 200 MGD can be efficiently handled by a single unit. The Barminutor combines the function of a bar screen with the unfailing performance of the Comminutor. It can be installed in existing open channels and has two to three times the cutting capacity of the standard Comminutor. Complete technical data sent upon request.

NEW! AT THE F·S·I·W·A CONVENTION
OCTOBER 6-9, 1952
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1. *Complete sludge digestion on an established schedule.*
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3. *Maximum use of digester capacities.*
4. *Accurate and regulated heating of digesting products.*
5. *Efficient direct heat transfer.*
6. *Economical and automatically controlled.*

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SEWAGE EQUIPMENT DIVISION

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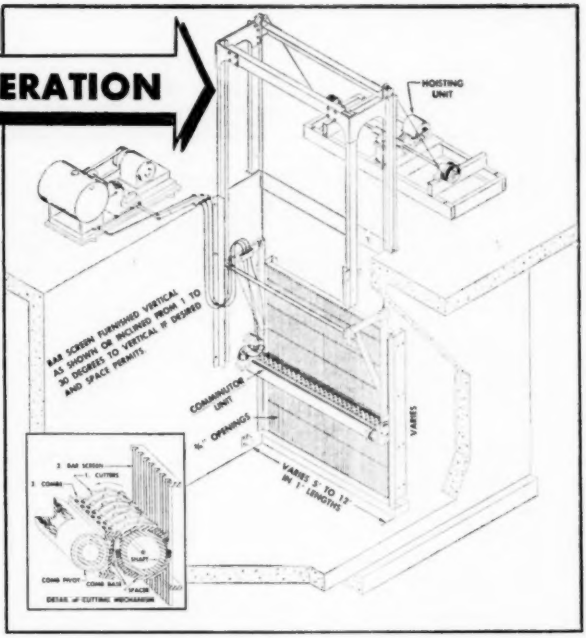
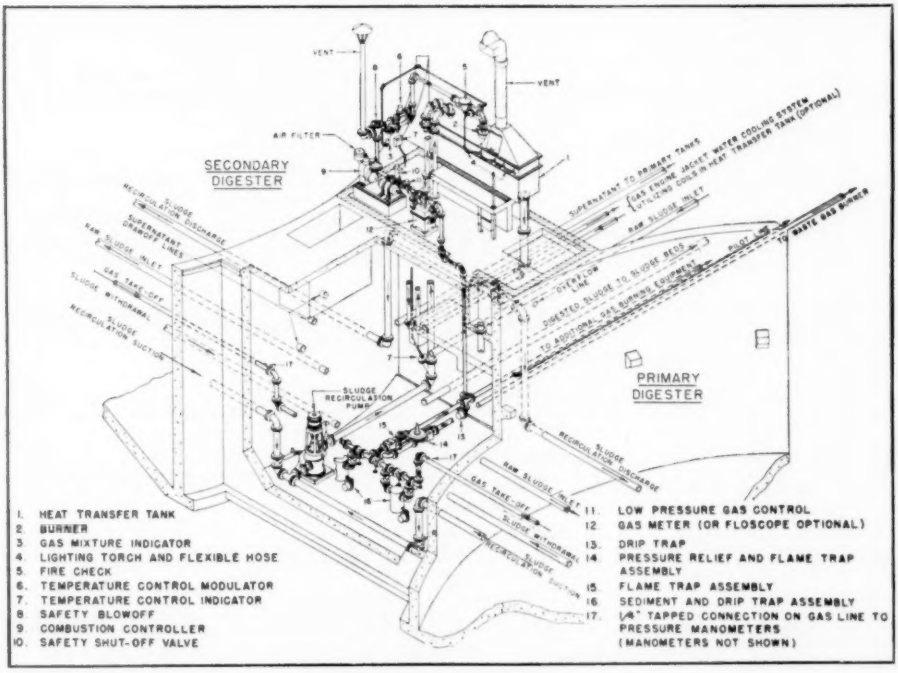
Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

BARMINUTOR OPERATION

Revolving cutters (1) traveling in slots on bar screen (2) pick up coarse sewage matter from screen and carry it to combs (3) against which it is cut into small pieces. Cutter assembly rotates at 200 rpm, and moves up and down the bar screen at 1 fpm. Rotating assembly swings away from bar screen and passes over heavy obstacles lodged against screen. Comb position shown above is for rotation indicated and upward travel; for downward travel rotation automatically reverses and lower comb engages.


HOISTING UNIT
BAR SCREEN FURNISHED VERTICAL AS SHOWN OR INCLINED FROM 1 TO 30 DEGREES TO VERTICAL IF DESIRED AND SPACE PERMITS
COMMINUTOR UNIT
½" OPENINGS
VARIES
VARIES 5' TO 12' IN 1' LENGTHS
DETAIL of CUTTING MECHANISM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AIR FILTER
SECONDARY DIGESTER
PRIMARY DIGESTER
SUPERNATANT TO PRIMARY TANKS
GAS ENGINE JACKET WATER COOLING SYSTEM (UTILIZING COILS IN HEAT TRANSFER TANK (OPTIONAL)
RAW SLUDGE INLET
TO WASTE GAS BURNER
DIGESTED SLUDGE TO SLUDGE BEDS
TO ADDITIONAL GAS BURNING EQUIPMENT
PILOT
SLUDGE RECIRCULATION DISCHARGE
SUPERNATANT DRAWOFF LINES
RAW SLUDGE INLET
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SLUDGE RECIRCULATOR PUMP
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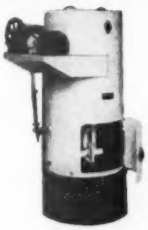

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HOW TO MEASURE TRADE WASTES ACCURATELY

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This purification process usually requires special plant construction, and invariably the necessity exists of obtaining flow data, whether this be the simple indication of flow rate or a more permanent method of recording and totalizing the flow through the plant. With purification processes of this kind, measuring equipment usually is located at the point of discharge of partially filled pipe or in open channels, where low heads or pressures exist and where measurement is either difficult or impossible when using standard forms of measuring instruments.

The Simplex type S Parabolic flume, either alone or in conjunction with a Simplex type HF water float operated meter, is the ready answer to this measuring problem. Compact in design, with no pockets or grooves to catch sediment or solids, and capable of operating under low flow conditions, the unit measures over long ranges, from maximum to 5% of maximum capacity.

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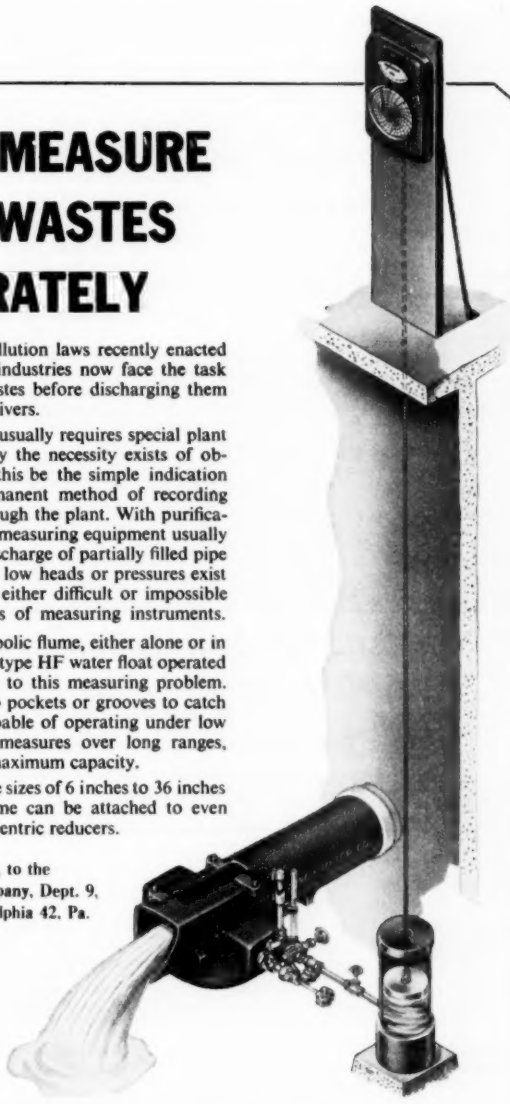

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Rocky Mt. Sewage Works Assn.	Frontier Hotel, Cheyenne, Wyo.	Sept. 15, 1952
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Johnson Hotel, Knoxville, Tenn.	Sept. 15–17, 1952
South Dakota Water and Sewage Works Conference	St. Charles Hotel, Pierre, So. Dakota	Sept. 17–19, 1952
German Sewage Technologists Assn.	Weisbaden, Germany	Sept. 17–20, 1952
Mo. Water and Sewerage Conference	Governor Hotel, Jefferson City, Mo.	Sept. 21–23, 1952
Georgia Water and Sewage Association	Georgia Inst. of Technology, Atlanta, Ga.	Sept. 24–26, 1952
North Dakota Water and Sewage Works Conference	Gladstone Hotel, Jamestown, N. D.	Oct. 2–3, 1952
West Virginia Sewage and Industrial Wastes Assn.	Chancellor Hotel, Parkersburg, W. Va.	Oct. 3–4, 1952

SILVER ANNIVERSARY MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
New York Sewage and Industrial Wastes Association
Hotel Statler, New York City
October 6–9, 1952

Pacific Northwest Sewage and Industrial Wastes Assn.	Multnomah Hotel, Portland, Ore.	Oct. 23–24, 1952
The Canadian Institute on Sewage and Sanitation	Seigniory Club, Montebello, Que.	Nov. 3–5, 1952
New England Sewage and Industrial Wastes Assn.	Taunton Inn Taunton, Mass.	Nov. 5, 1952
North Carolina Sewage and Industrial Wastes Assn.	Skyland Hotel, Hendersonville, N. C.	Nov. 10–12, 1952
Florida Sewage and Industrial Wastes Association	San Carlos Hotel, Pensacola, Fla.	Nov. 16–19, 1952

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SINGLY . . . OR IN COMBINATION

. . . especially in the treatment of strong industrial wastes

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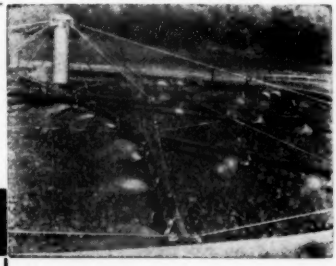

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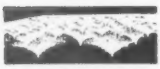

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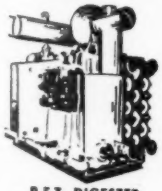

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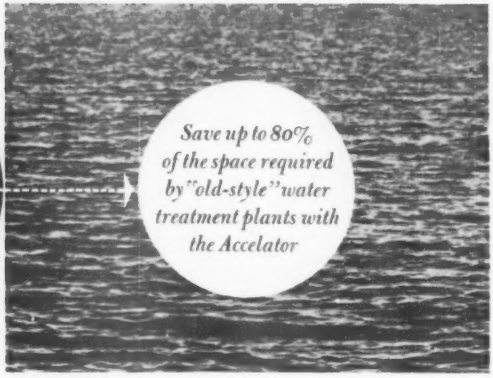

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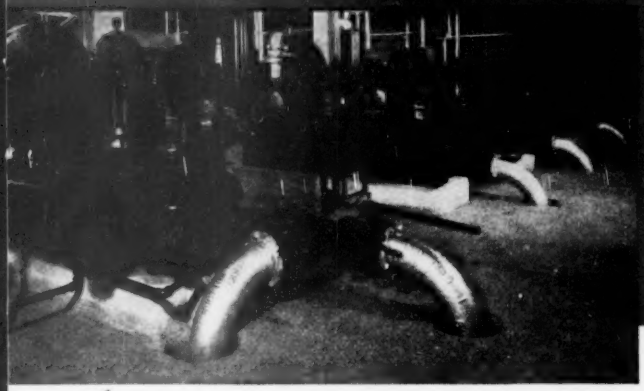
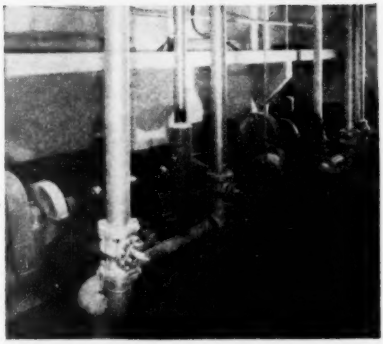
MAKE NORDSTROMS *Best* FOR SEWAGE PUMP LINES

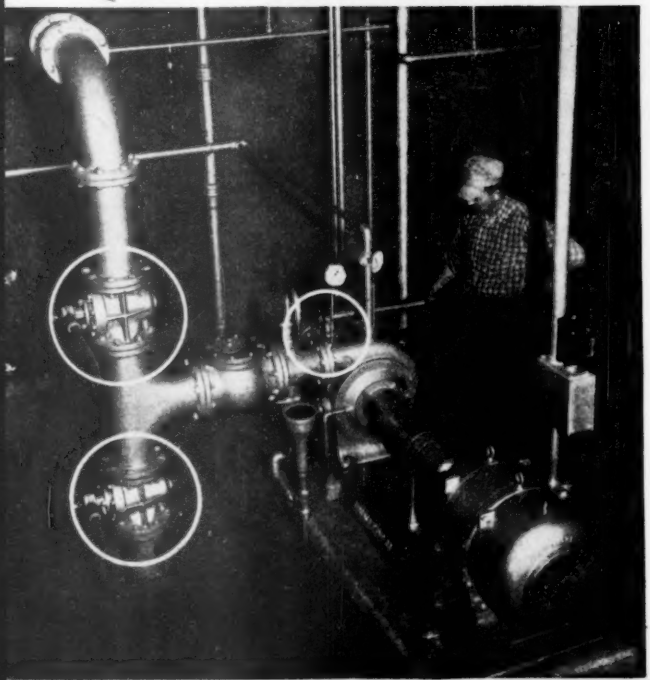




Nordstrom valves on displacement sludge pumps.

Easy-to-operate Nordstroms at head of main pump lines.

Emergency centrifugal sludge pump with Nordstrom valve control.



In Nordstrom valves there are no pockets or recesses to collect foreign matter. When a Nordstrom valve is open the seating surfaces are out of the line of flow, protected from erosive or corrosive substances. And, open or closed, the internal lubrication system forms an uninterrupted ring of protective, plastic-type lubricant around the seat port for drop-tight closure, even after years of hard service.

These features combine to make Nordstrom valves best for the exceptionally difficult conditions in sewage treatment lines. Typical of these demanding services are pump lines.

For all types of sewage plant pump lines . . . in fact, for almost any sewage plant service, you'll be money ahead to specify Nordstroms from the start.

Typical Nordstrom Services In Sewage Treatment Plants

Lateral Air Lines	Water
Sludge Lines	Metering Lines
Grit Chamber Drain Valves	Digester Lines
Pump Suction and Discharge	Filter Lines
Sewage Gas	Bucket Elevator Lines

Write for Bulletin No. 1031 describing Rockwell-built Nordstrom valves, gas meters and water meters for sewage service.

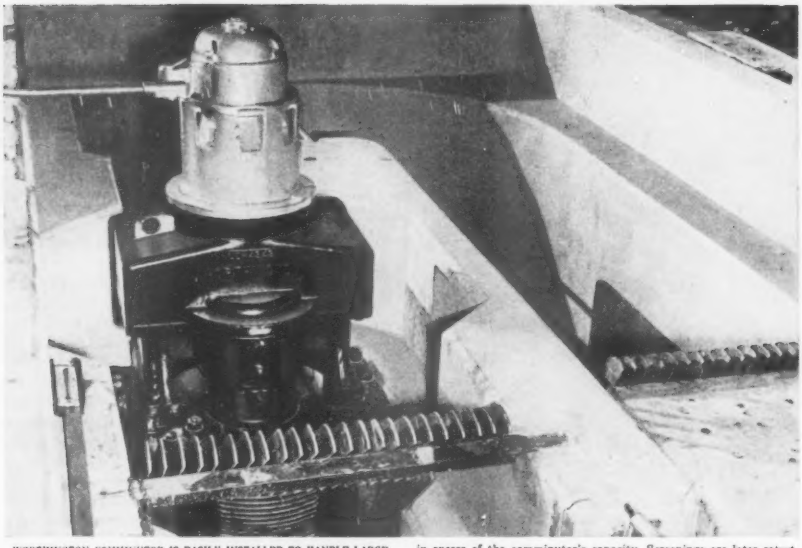
Rockwell Built Nordstrom Valves

Lubricant Sealed to Keep Upkeep Down

Rockwell Manufacturing Company

400 N. Lexington Ave., Pittsburgh 8, Pa.

Another ROCKWELL Product



WORTHINGTON COMMINUTOR IS EASILY INSTALLED TO HANDLE LARGE VARIATIONS IN FLOW like this one at the Madison-Chatham (N. J.) Sewage Treatment Plant. Maximum wet-weather flows are occasionally as high as five times the average design dry-weather flow. An overflow screen is installed on top of the comminutor to screen flows in excess of the comminutor's capacity. Screenings are later raked down into the comminutor during period of normal flow. The overflow screen makes the comminutor independent of the by-pass on right which may later be used as a channel for a second comminutor. Plant Superintendent is Edward P. Molitor.

Madison-Chatham, N. J., installation proves adaptability of Worthington COMMINUTOR

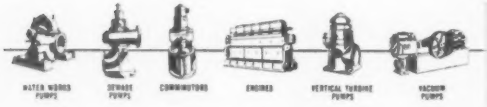
Typical example of the adaptability of the Worthington comminutor is the story of this installation at the Madison-Chatham Joint Meeting Sewage Treatment Plant in Chatham, N. J.

Engineers everywhere especially like the Worthington comminutor because:

- It can be readily installed in new or existing straight-flow rectangular channels.
- Cutter-racks are quickly removable for sharpening or replacement.
- It may be flooded without damage because it's protected by a mercury seal.

Worthington's public works specialists are ready to work with your community's engineer in solving screening problems—as well as other problems in sewage, water works, or municipal power generation. Write for Comminutor Bulletin W-2010-B3. Worthington Corporation, formerly Worthington Pump and Machinery Corporation, Public Works Division, Harrison, N. J.

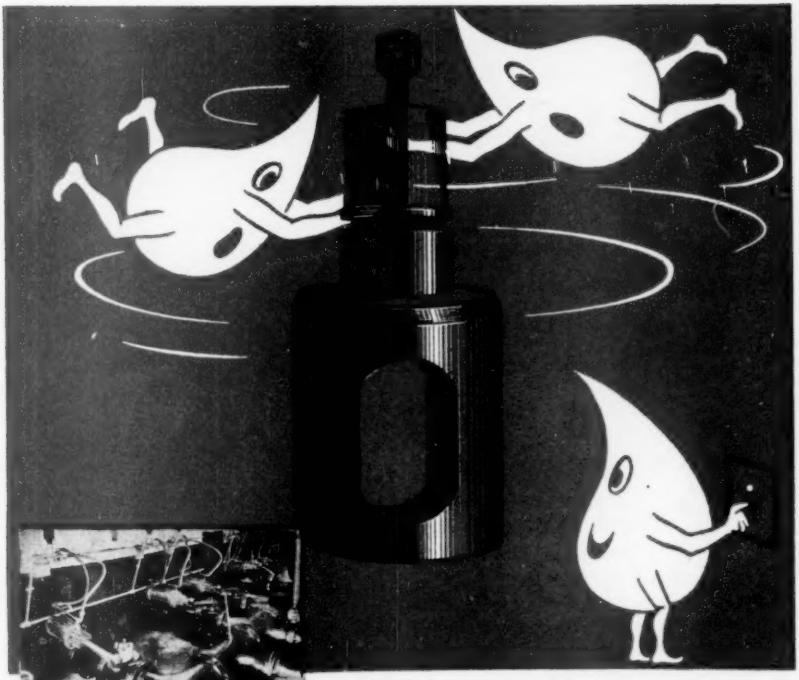
W.2.5

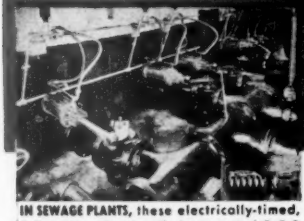


All Major Public Works Equipment Under One Responsibility

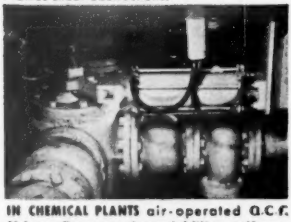
WORTHINGTON

Public Works Equipment





IN SEWAGE PLANTS, these electrically-timed, fully-automatic, air-cylinder operated Q.C.f. Valves shear obstructions.



IN CHEMICAL PLANTS air-operated Q.C.f. Valves offer super-dependability...self protected from abrasive and corrosive action.

IN THE STEEL INDUSTRY Q.C.f. Valves provide split-second control of fuel oil and gas to furnaces and coke ovens.

SPLIT SECOND ROBOT CONTROL

Q.C.f. CYLINDRICAL Plug Valves are ideal for all types of automatic operation: hydraulic, electrical, or air operated. The quick quarter-turn from full-open to full-closed is always sure as there's no wedge effect to cause jamming in the seat. In addition, all bearing surfaces are lubricated for easy turning. Sound reasons to insist on Q.C.f. Plug Valves for all automatic valve operations.

Q.C.f. CYLINDRICAL FULL PIPE AREA PLUG VALVES

Write for Catalog 4-SI, American Car and Foundry Co. Valve Division, 1501 E. Ferry Ave., Detroit 11, Michigan

Representatives in 50 Principal Cities

NOTES

for the engineer's note book

—ON—

Pumping with Economy

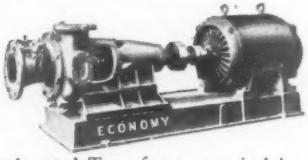
FOR SEWAGE MEN:

UNSCREENED SEWAGE HANDLED By Wheeler-Economy Non-Clog Centrifugal Pumps

For DRY PIT installations:

Wheeler-Economy Horizontal or Vertical Centrifugal Sewage Pumps have clear waterways from 1½" to 10". They pump unscreened sewage, miscellaneous pulp or trash in liquid without difficulty. Where sewage is screened, Mixed Flow types are available for higher speed, more economical operation. Sizes to 36".

"Sentry" Type vertical pump with motor direct connected. For dry pit service, not subject to flooding, and to conserve floor space. CATALOG F249.



Horizontal Type for economical installation, accessibility and to simplify maintenance. CATALOG F447.

Open Shaft Type vertical pump with flexible shafting drive from motor. Motor located at distance above pump to avoid possible flooding of electrical equipment and to conserve pump room floor space. CATALOG F249.

For WET PIT installations:

WHEELER-ECONOMY Sump Pumps

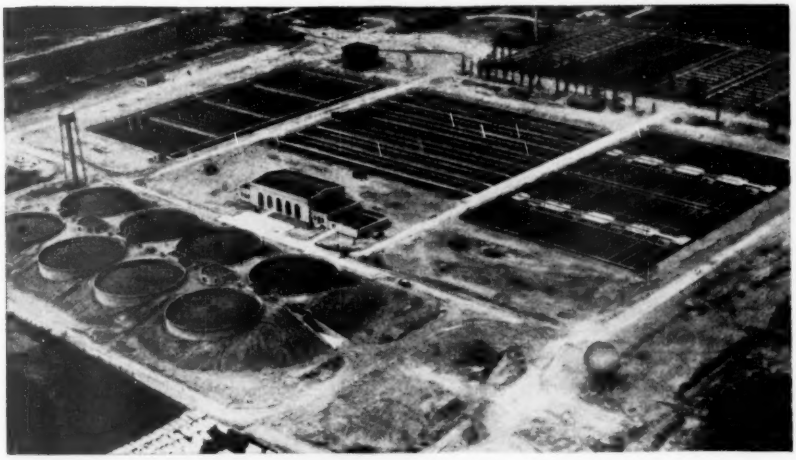
Designed in single or duplex units to elevate drainage or sewage from wet pits, sumps, basements, boiler pits, scale and elevator pits, etc. Sizes from 1½" to 3" for drainage free from solids. Sizes 3" to 14", non-clog type for unscreened drainage containing solids. Sump cover and control arrangements can be supplied to meet any requirements. CATALOG E748 for General Service. CATALOG E345 for Non-Clog.

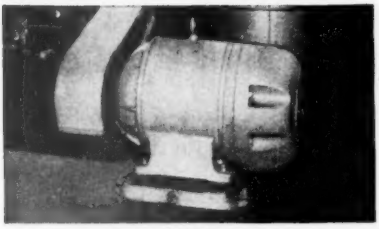
See Your Phone Directory or Write Us for Name of Nearest Distributor for ECONOMY PUMPS, Inc.

121-S

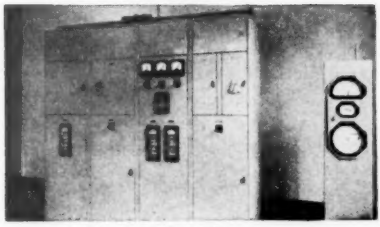
WHEELER-ECONOMY PUMPS

ECONOMY PUMPS, INC. • DIVISION OF C. H. WHEELER MANUFACTURING CO.
19TH AND LEHIGH, PHILADELPHIA 32, PA.

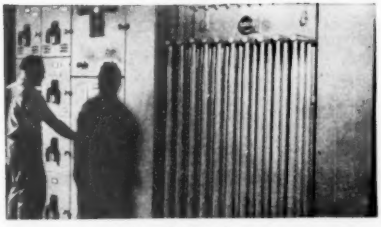




Motors



Control



Unit Substations

G-E application engineers select products like these to form the co-ordinated electrical system that exactly fits your plant requirements.

Here's Help on Your Campaign for

CLEAN WATERS

General Electric helps make your pollution-control program a success in three ways:

1. Aids you in winning public support through the G-E packaged program "Modern Sewage Treatment" including the color sound movie *Clean Waters*.

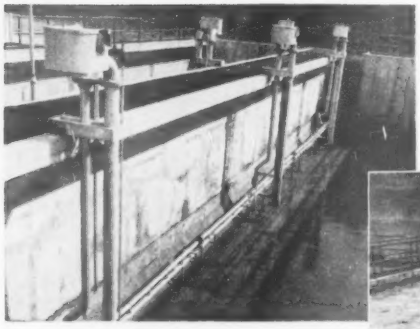
2. Assists your engineers or consultants in the formation of electrical plans.

3. Manufactures a complete line of dependable electric equipment for sewage treatment plants.

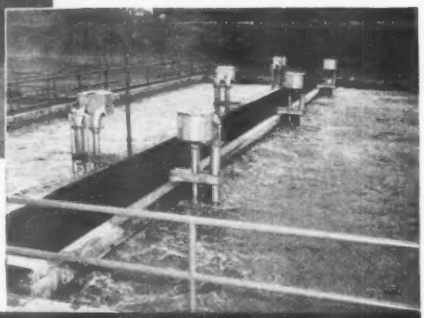
To take advantage of this complete, three-way service, contact your G-E representative *early in the planning stage* when he can help you most. *General Electric Co., Schenectady 5, N. Y.*

GENERAL ELECTRIC

666-69



DIFFUSAIR installation at Kirkwood, Mo. Impingement nozzles and bowls are on headers at lower left side of tank.



DIFFUSAIR at Kirkwood, Mo. in operation showing effective "spiral flow" agitation and aeration of tank liquor.

impingement aerator **DIFFUSAIR**

FOR

SEWAGE

WASTE AND

WATER TREATMENT

PRE-AERATION . . .

ACTIVATED SLUDGE . . .

CARBONATION

The Impingement Aerator is a unit developed to accomplish more effectively and economically the diffusion of air as small bubbles to agitate and oxygenate aeration tank liquors.

The principle involved is the combining of a low velocity jet of tank liquor and large air bubbles within an open bowl-like impinger. The cavitation effect thus produced divides the air into smaller bubbles than those diffused from a No. 30 permeability porous tube. The amount and pressure of the impingement water is very low when compared with the progressive back pressuring of the blower that persists when other types of air diffusers are employed.

The impingement liquor is derived directly from the aeration tank mixed liquor, and is lifted with a simple air-lift unit from which 1/3 of the fine air is re-entrained and utilized for oxygenation.

The air is released along headers through 3/16 inch orifices in the impinger units and no air clogging is possible. No filtering of the compressed air supply is required since there are no fine diffusion pores to become clogged.

Write for Bulletin 17531

PROQUIP PROCESS EQUIPMENT

WALKER PROCESS EQUIPMENT INC.

FACTORY · ENGINEERING OFFICES · LABORATORIES

AURORA, ILLINOIS

How's this for putting brains to work?

For more than 70 years, Cook Well Strainer Company, Inc., of Lawrenceburg, Indiana, has been making well strainers. For many of these years slotted seamless brass tubes, up to 12″ in diameter, proved wholly adequate. But the insistent demand for more and more water called for deeper wells with larger diameters—and strainers to meet the new needs.

The basic features of the famously successful tube strainer—direct inlet; self-cleaning slot, larger inside than outside; one metal; strength; rigidity—would have to be duplicated in larger diameters.

Why not a wire-wound strainer with automatically made *mechanical* bonds? Indeed, why not? The illustrations on this page show the practical application of this ingenious idea. Cook Wire-Wound Well Strainers are now made in sizes up to 40″ inside diameter—at high speeds, with slot widths readily variable, and lengths limited only by handling facilities.

Two ANACONDA Metals, Red Brass-24 and Everdur*-1010 Copper-Silicon Alloy, are outstanding for this application. Both machine readily, withstand upsetting, contribute strength and rigidity, and provide excellent resistance to corrosive ground waters. The American Brass Company, General Offices, Waterbury 20, Connecticut. 5292-B

*Reg. U. S. Pat. Off.

16″ diameter, 35-foot-long Cook Well Strainer made of Everdur being installed at Fort Knox, Kentucky.

As the supporting skeleton of bars revolves in this winding machine, each bar is machine-notched ahead of the spirally wound wire (see circle illustration). This wire is a specially drawn AnacondA Shape of modified keystone cross-section. A circular form tool then displaces the metal on one side of the V-groove into the dovetail section of the wire, locking it securely.

the name to remember

ANACONDA®

COPPER, BRASS & BRONZE

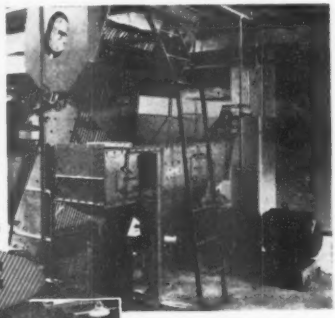
IMPROVED BACK-CLEANED

SCREENS

Jeffrey pioneered in the development of the Back-cleaned Screen—has over ten years of experience in the design and building of this type of mechanization.

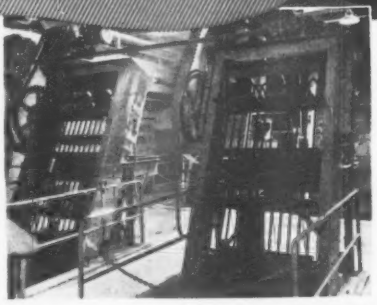
It is available in either inclined or vertical position—is highly recommended for all difficult screening problems, whether the plant is small or large. It is fool-proof. Dozens of installations prove its dependability and low maintenance.

OVER 10 YEARS PROVEN PERFORMANCE



Above — Two of four fine Screens installed in the 26th Ward Sewage Treatment Works, New York City

Also:
SLUDGE COLLECTORS
SLUDGE ELEVATORS
FLOCTROLS
GRIT WASHERS
GRIT COLLECTORS
BAR SCREENS
RAPID MIXERS
GRINDERS
CHEMICAL FEEDERS
CHAINS



Above—rear view of the Fine Screens (upper left) in the 26th Ward Plant showing Jeffrey Belt Feeder and Screening Grinder

Left — Two of four coarse heavy duty Screens at the same plant.

Send for Catalog No. 833

THE JEFFREY MANUFACTURING COMPANY
902 North Fourth St., Columbus 16, Ohio
ESTABLISHED 1877

OUR 75th ANNIVERSARY

USE THIS DOUBLE-EDGED WEAPON

TO COMBAT SEWER FAILURES

You can provide the two essentials of good sewer performance — structural strength and material durability — by specifying Armco ASBESTOS-BONDED Pipe. It gives you a strong conduit and utmost protection against severe corrosion.

Flexible, corrugated metal construction assures ample strength to withstand the impact and vibration of heavy traffic. Sturdy coupling bands make the joints in ASBESTOS-BONDED Pipe as tight and strong as the pipe itself.

Severe corrosion is no problem because millions of asbestos fibers are anchored in the galvanizing and saturated with a bituminous seal coat to protect the base metal. This material is rot-proof and non-deteriorating. It assures long, trouble-free service.

Armco ASBESTOS-BONDED Pipe is ideal for handling severe corrosion. Where erosion is also a problem use ASBESTOS-BONDED PAVED-INVERT; if headroom is limited use ASBESTOS-BONDED PIPE-ARCH. Write for complete data. Armco Drainage & Metal Products, Inc., 1782 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

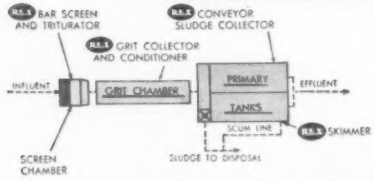
Armco ASBESTOS-BONDED Pipe

ARMCO

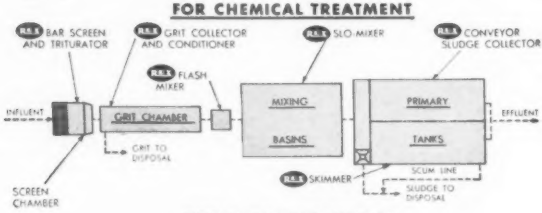
for best

PLAN YOUR PLANT

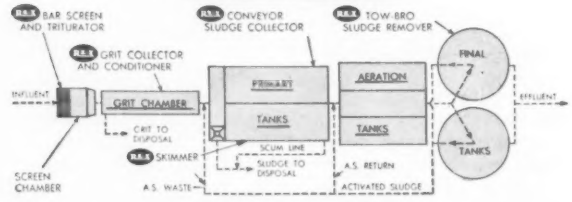
FOR PRIMARY TREATMENT



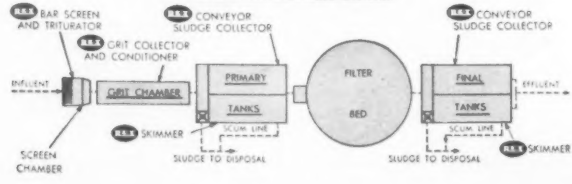
FOR CHEMICAL TREATMENT



FOR ACTIVATED SLUDGE



FOR TRICKLING-FILTER



RESULTS

ALONG THE REX LINE

Here's Why!

1. Modern treatment plants, regardless of size or type of process, require a multiplicity of arrangements and units.

2. The complete Rex line provides a broad selection of equipment that will best fit your requirements.

3. Selection of the *right* equipment is extremely important. The finest equipment in the world will not perform efficiently and economically if it is improperly applied.

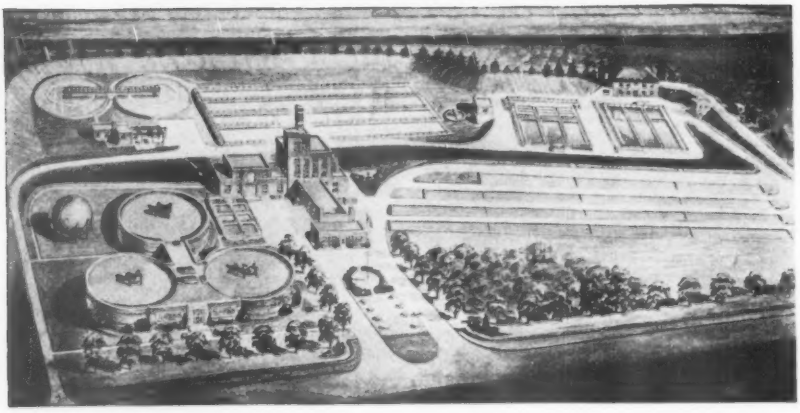
4. Rex Sanitation Engineers are well qualified by years of training and experience to help you select the equipment which will best fit into your plans. Call them in when your job is still in the planning stage. You'll find it pays off in greater plant efficiency, improved performance, lower operating and maintenance costs. Chain Belt Co., 4606 W. Greenfield Ave., Milwaukee 1, Wis.

Chain Belt COMPANY
OF MILWAUKEE

CHAIN BELT REX COMPANY ®

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago
Cincinnati • Cleveland • Dallas • Denver • Detroit • El Paso
Houston • Indianapolis • Jacksonville • Kansas City • Los Angeles
Louisville • Midland, Texas • Milwaukee • Minneapolis • New York
Philadelphia • Pittsburgh • Portland, Oregon • Springfield, Mass.
St. Louis • Salt Lake City • San Francisco • Seattle • Tulsa • Worcester
Export Offices: Milwaukee and 19 Rector Street, New York City

New Disposal Plant at York



Designed and supervised by ***Albright & Friel Inc.***
Consulting Engineers

Under construction by ***McElwee-Courbis, Inc.,***
and Ertel Construction Co.,
Camden, N. J.

C-E Raymond Systems installed, under construction or on order since 1945

Installation	Consulting Engineer
Baltimore, Md.	Whitman, Requardt & Associates
Bethlehem, Pa.	Morris Knowles
Bloomsburg, Pa.	Gannet, Fleming, Corddry & Capper
Camden, N. J.	Havens & Emerson
Chicago, Ill. (W. Southwest)	City Engineering Dept.
Fond du Lac, Wis.	Jerry Donohue Engrg. Co.
Houston, Texas	Greeley and Hansen
Lansing, Mich.	Drury, McNamee and Porter
Los Angeles, Cal.	Metcalf and Eddy
San Diego, Cal.	Frank Currie
San Francisco, Cal.	Clyde C. Kennedy
Schenectady, N. Y.	Havens and Emerson
Sheboygan, Wis.	Jerry Donohue Engrg. Co.
Washington, D. C.	Greeley and Hansen
Waterbury, Conn.	Malcolm Pirnie
Wyomissing Valley, Pa.	Albright & Friel
York, Pa.	Albright & Friel

Industrial sludges a problem?
C-E Raymond Flash Drying and Incineration Systems have been the answer for others. Write for information.

In line with Pennsylvania's campaign to end stream and atmospheric pollution, the City of York has started work on its modern, sewage treatment plant.

The new plant is designed for a flow of 12 million gallons daily, to meet the needs of a future population of 90,000, with a heavy industrial load.

To dry digested sludge at York, there will be a C-E Raymond Flash Drying Unit capable of drying or incinerating 51 tons of filter cake per 7 hour day — equivalent to evaporating 9,820 pounds per hour. High temperature deodorization will eliminate objectionable odors.

C-E Raymond Systems are flexible, efficient and reliable; they provide for maximum utilization of waste heat. They have met the needs of communities ranging from 6,000 to 3,000,000.

The services of C-E specialists are available to help you find the best solution to your sludge disposal problems.

B-590A

COMBUSTION ENGINEERING–SUPERHEATER, INC.

FLASH DRYER DIVISION

1315 North Branch Street
Chicago 22, Illinois

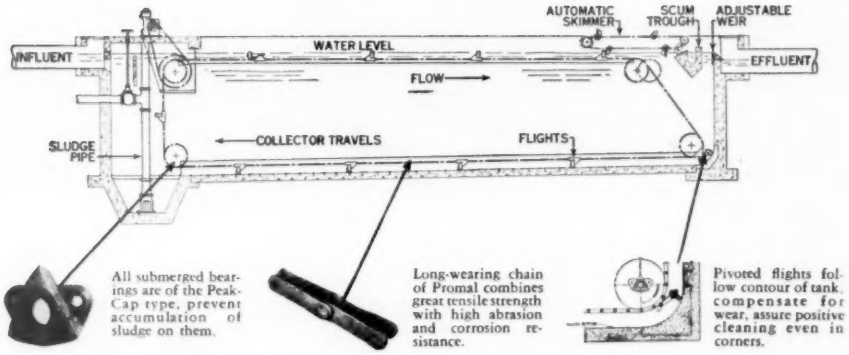
Western Office: 560 W. Sixth, Los Angeles 14, Calif.
Eastern Office: 200 Madison Ave., N. Y. 16, N. Y.

OUR EXHIBIT — SEWAGE WORKS & INDUSTRIAL WASTES ASSOCS. — OCT. 6-9 — NEW YORK CITY

LINK-BELT Straightline Sludge Collectors help treat

2 BILLION GALLONS

of sewage per day


AUTOMATIC SKIMMER
SCUM TROUGH
ADJUSTABLE WEIR
INFLUENT
WATER LEVEL
EFFLUENT
FLOW
SLUDGE PIPE
COLLECTOR TRAVELS
FLIGHTS
All submerged bearings are of the Peak-Cap type, prevent accumulation of sludge on them.
Long-wearing chain of Promal combines great tensile strength with high abrasion and corrosion resistance.
Pivoted flights follow contour of tank, compensate for wear, assure positive cleaning even in corners.

Easy, economical sludge removal provided for water and industrial waste treatment plants

Since the first Straightline Sludge Collector went into service at Gastonia, N. C., in 1921, the great majority of the country's rectangular settling tanks have been equipped with this Link-Belt design. Straightline action provides the shortest possible travel of collected material at slow, uniform speed. Result: minimum disturbance of flow and maximum efficiency. In addition, they have a proven record for uninterrupted operation with minimum attention.

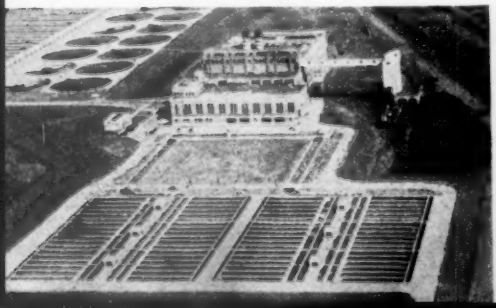
Straightline Collectors are part of the complete Link-Belt line of quality equipment. Our sanitary engineers will be glad to work with your engineers, chemists and consultants—help you get the best in modern water, sewage or industrial liquids treatment equipment.

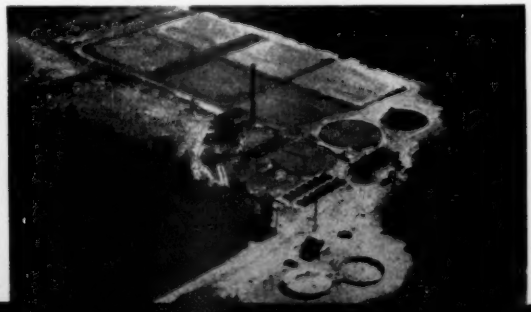
LINK-BELT

SANITARY ENGINEERING EQUIPMENT

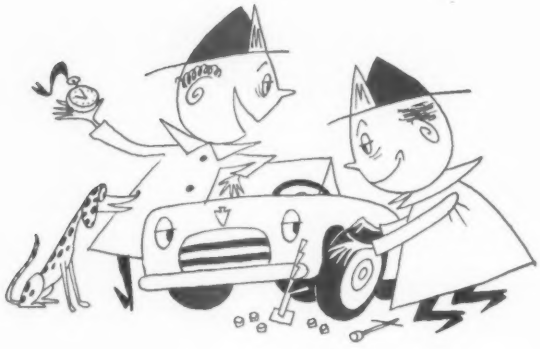
LINK-BELT COMPANY: Plants: Chicago, Indianapolis, Philadelphia, Atlanta, Houston, Minneapolis, San Francisco, Los Angeles, Seattle, Toronto, Springs (South Africa), Sydney (Australia). Sales Offices in Principal Cities. 12,972

Straightline Collectors, for both primary and final settling tanks, equip plants from 80,000 up to 600,000,000 gpd. Shown here: a 600,000,000 gpd plant (left) and 6,000,000 gpd (right).





Quick as changing a wheel



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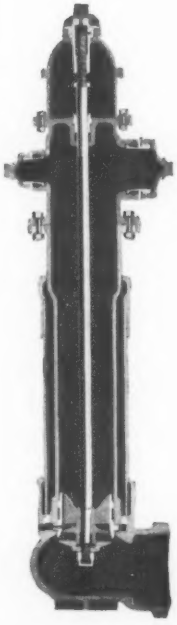

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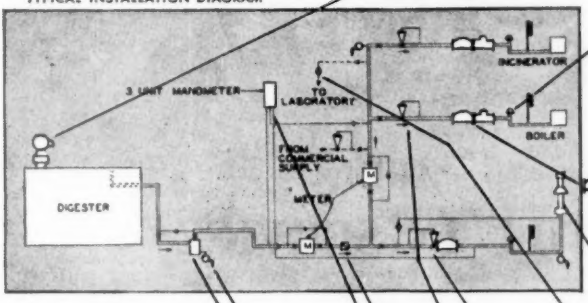

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 24 | September, 1952 | Number 9

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Sewage Works

DETERGENTS AND SEWAGE TREATMENT *

By Raymond Manganelli

Rutgers University, New Brunswick, N. J.

Within the last 10 years, many detergents have been patented and placed on the market. It has been estimated that in 1941 there were 200 brand name products, whereas at present some 700 brand name surface active agents are being sold for specialized purposes (1) (2).

The production of detergents in the United States has steadily increased from 28,000,000 lb. of 100 per cent active material in 1941 to 1,500,000,000 lb. in 1951. This represents an increase in synthetic detergent sales from approximately 1 per cent to 54 per cent of that of soap during the past decade. The anionic agents account for about 90 per cent of the total bulk, of which more than 40 per per cent is of the alkyl aryl sulfonate type (3).

Surface active agents are usually characterized by a molecular structure consisting of a hydrophobic and a hydrophilic portion. The classification of synthetic detergents is ordinarily based on the nature of the hydrophilic group with respect to its electrical charge or nonionizable character. The three main categories, with examples of each, are as follows:

1. Anionic detergents, such as the alkyl sulfates (Duponol C, Dreft) and the sodium alkyl aryl sulfonates (Nacconol, Santomerse, Fab). The majority of household detergents fall into this class.

2. Nonionic agents, such as the condensation products of polyoxyethylene with fatty acids and alkyl phenols (Tween, Glim). At present most agents of this type are employed for industrial purposes.

3. Cationic agents, such as pyridinium derivatives (Ceepryn) and quarternary ammonium compounds (Hyamine). The members of this group have been used for sanitizing utensils and equipment, particularly in restaurants.

The general correlation of chemical structure of surface active agents with certain predominating properties, such as wetting, dispersing, and detergency, has permitted the fabrication of these products for specific purposes. The synthetic detergents have become an integral part of the daily household routine and many industrial processes, including those of the textile, cosmetic, metal, food, leather, paper, and rubber industries.

The presence of synthetic detergents in sewers and their effect on sewage treatment devices with respect to efficiency and operational difficulties has brought forth uneasiness and concern.

In a previous paper (4), the principal effects of household detergents were examined. The present paper deals briefly with the effects produced by representatives of the three main types of surface active agents—Nacconol N. R. (anionic), Tween 80 (nonionic), and Ceepryn (cationic)—in

* Paper of the Journal Series, New Jersey Agricultural Experiment Station. Presented at 37th Annual Meeting, New Jersey Sewage and Industrial Wastes Association; Atlantic City, N. J.; March 12–14, 1952.

quantities of 5 to 100 p.p.m., which cover the concentration range expected in domestic sewage, on various phases of the problem.

Effect on Sewage Oxidation

Some anionic detergents (such as Dreft) are readily oxidized in concentrations of 1,000 p.p.m., whereas others (such as Nacconol N.R.) display a tendency to interfere with the oxidation of sewage at concentrations above 100 p.p.m. The effects of cationic Ceepryn and nonionic Tween 80 on sewage oxidation are illustrated in Figure 1. The toxic effect of Ceepryn, with attendant retardation of sewage oxidation, increased with increasing concentrations (5 to 100 p.p.m.) of the detergent. Tween 80, amenable to biological decomposition, caused no interference with the oxidation of sewage and yielded higher B.O.D. values as the quantity of agent was increased from 5 to 100 p.p.m. Hence, the types of detergents (such as Nacconol and Tween 80) which are finding greatest application for domestic and industrial functions induce no suppression of sewage oxidation in concentrations up to 100 p.p.m. and, consequently, present no problem so far as their direct action on biological devices is concerned. However, detergents of the Ceepryn type may affect the rate and degree of sewage oxidation.

Effect on Oxidation by Activated Sludge

A series of experiments employing a Warburg respirometer were made to determine the effect of anionic, nonionic, and cationic detergents on the oxygen uptake of 1,000 p.p.m. of activated sludge in the presence and absence of domestic sewage. Some of the results are illustrated in Figures 2 and 3. It was found that Tween 80 (nonionic) in concentrations up to 100 p.p.m. did not interfere with the oxygen uptake of the activated sludge or with the oxidation of sewage by the sludge. Tween 80 served as additional organic food for the sludge organisms,

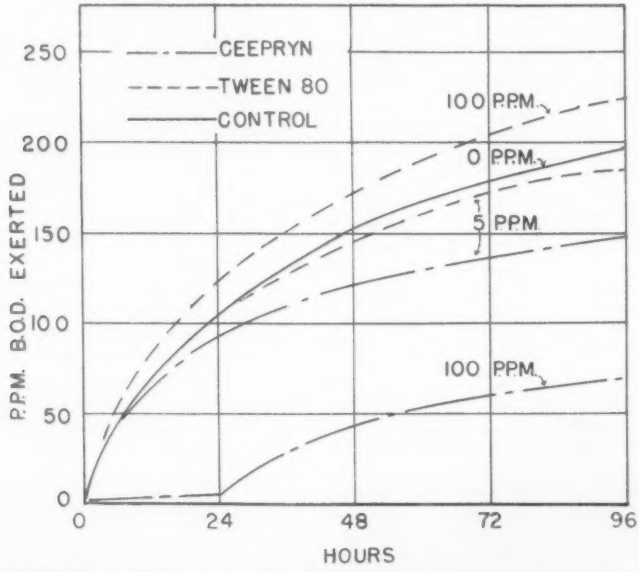

FIGURE 1.—Effect of Ceepryn and Tween 80 on oxidation of sewage.

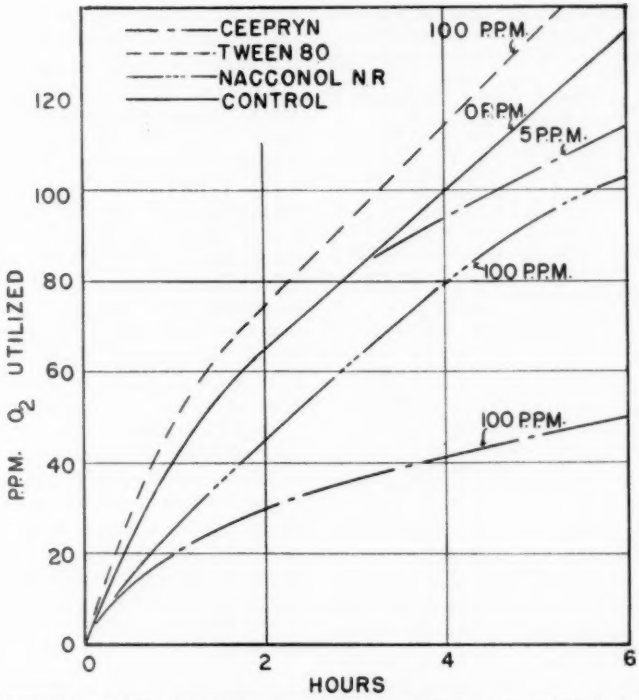

FIGURE 2.—Effect of detergents on oxidation of sewage by activated sludge.

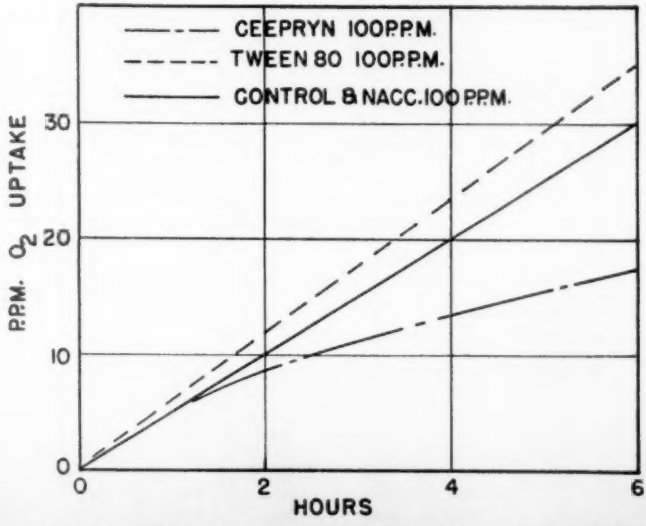

FIGURE 3.—Effect of detergents on oxygen uptake of activated sludge.

TABLE I.—Analyses of Mixtures with 100 p.p.m. Detergent During Digestion

Detergent	Time (days)	pH	Solids		Grease	
			Tot. (%)	Vol. (%)	(%)	Red. (%)
None[1]	0	6.6	6.93	60.2	11.2	—
	7	6.4	6.27	56.3	—	—
	14	6.8	6.10	55.4	—	—
	21	6.6	5.96	54.8	—	—
	31	6.8	6.00	54.4	6.7	40
Nacconol N.R.	0	6.6	—	—	—	—
	7	6.4	6.20	56.6	—	—
	14	6.8	6.02	54.8	—	—
	21	6.7	6.03	55.0	—	—
	31	6.8	5.91	54.6	6.9	38.4
Tween 80	0	6.6	—	—	—	—
	7	6.4	6.18	56.7	—	—
	14	6.8	6.00	55.7	—	—
	21	6.7	5.92	55.4	—	—
	31	6.8	5.93	55.0	6.6	41.0
Ceepryn	0	6.6	—	—	—	—
	7	6.4	6.29	56.8	—	—
	14	6.8	6.15	55.7	—	—
	21	6.7	6.05	55.0	—	—
	31	6.8	5.93	54.4	6.2	44.6

[1] Control

as manifested by the increase in oxygen utilization with increasing concentrations of the nonionic agent.

Nacconol N.R. (anionic) was employed in quantities of 10 to 100 p.p.m. based on active material, which is equivalent to approximately 25 to 250 p.p.m. of the total package product as ordinarily used. In concentrations expected in sewage, no suppression of the oxidation of sewage was exhibited. With increasing amounts of detergent, a suppression of the oxidation was generally encountered. No measurable effect on the oxygen uptake of the activated sludge itself was experienced in 6 hr.

Ceepryn (cationic) in concentrations ranging from 10 to 100 p.p.m. exerted an inhibitory effect on the oxidation of sewage by activated sludge. Presence of this agent in concentrations of 50 and 100 p.p.m. diminished the oxygen uptake of the sludge itself. The quantities of cationic detergent employed are higher than are normally expected in domestic sewage because of the limited

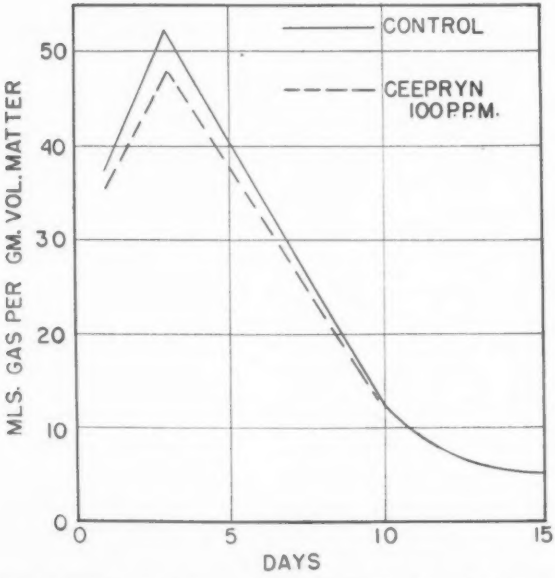

FIGURE 4.—Comparison of rates of gas production with and without detergent.

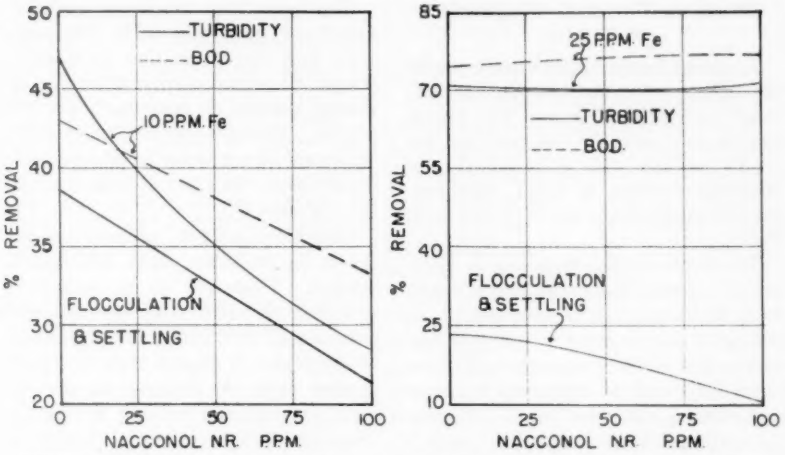

FIGURE 5.—Effect of Nacconol N.R. on coagulation of sewage with Fe (as $FeCl_3$).

and specialized usage of such agents. There is also the possibility that interaction with complex anionic compounds diminishes the toxic effect of cationic products.

Effect on Sludge Digestion

Nacconol N.R., Tween 80, and Ceepryn in quantities of 10, 25, 50, and 100 p.p.m. were added to a series of fresh solids-ripe sludge mixtures prepared on a volatile matter basis of 1:1. The mixtures were allowed to digest for 31 days at 20° C.

Some of the results obtained during digestion of mixtures containing 100 p.p.m. detergents are shown in Table I. The volatile matter destruction proceeded at approximately the same rate with all three detergents, and the grease reduction was about equal for the more widely used agents. Only slight retardation and reduction in gas production can be expected with detergent in quantities at the highest level expected in sewage (Figure 4). Lower concentrations of surface active agents caused some stimulation of gas production, which diminished as the detergent concentration increased.

TABLE II.—Effect of Detergents on Sludge Volume and Floc Size During Chemical Coagulation of Sewage

Fe, as $FeCl_3$ (p.p.m.)	Detergent (p.p.m.)	Nacconol N.R.		Tween 80		Ceepryn	
		Sludge (ml./l.)	Type of Floc	Sludge (ml./l.)	Type of Floc	Sludge (ml./l.)	Type of Floc
0	0	4.5	None	3.5	None	3.5	None
0	50	4.0	None	3.5	None	3.0	Pin point
0	100	3.5	None	3.7	None	6.5	Pin point
10	0	6.0	Medium	16.0	Large	8.0	Small
10	50	5.0	Small	5.0	Small	26	Large
10	100	4.5	Small	4.5	Small	32	Very small
25	0	34.0	Large	38.0	Large	33	Large
25	50	29.0	Large	35.0	Less floc	40	Very small
25	100	29.0	Large	26.0	Least	48	Very small

Effect on Chemical Coagulation of Sewage

A series of experiments dealing with the effects of detergents on the efficiency of purification and floc formation were made by coagulating domestic sewage with subminimal and optimum dosages of $FeCl_3$ and concurrent adjustment of pH to 5.0 with H_2SO_4.

The results with Nacconol N.R. (Figure 5) demonstrate the interference with flocculation and coagulation of sewage in the presence of low iron dosages. The dispersive action of Nacconol N.R. and its attendant interference with purification were overcome by optimum iron dosage (25 p.p.m.) for the raw sewage. Similarly, the diminishing effect of Nacconol on the floc size from low coagulant dosage disappeared upon addition of optimum coagulant dosage. A brief summary of floc formation and sludge accumulation data is shown in Table II.

The impairing effect on turbidity and B.O.D. removals, sludge accumulation, and floc formation ascribed to Tween 80 persisted even when the optimum dosage of coagulant was employed. The effective dispersive action of Tween 80 could not be alleviated by a very high (50 p.p.m.) dosage of iron salt (Figure 6).

Cationic Ceepryn induced an increase in turbidity upon addition to sewage. However, an increased removal of turbidity was obtained with subminimal iron dosage in the presence of Ceepryn. A higher degree of purification upon the addition of the cationic detergent is evident in the increase in sludge volume produced, as well as by the B.O.D. removals. Greater amounts of Ceepryn caused an increase in floc size with low coagulant dosage and a diminution of floc size with optimum dosage of the iron salt, whereas lower quantities of Ceepryn had less effect.

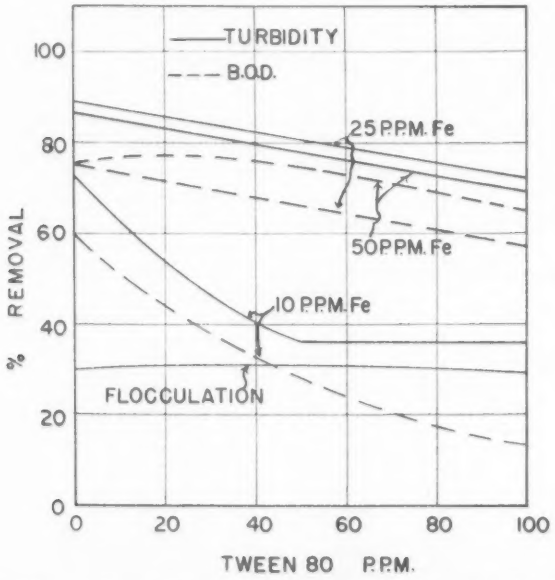

FIGURE 6.—Effect of Tween 80 on chemical coagulation of sewage with Fe (as $FeCl_3$).

TABLE III.—Effect of Detergents on Coliforms During Settling

Detergent (p.p.m.)	Organisms per Ml. in the Effluent		
	Nacconol N.R.	Tween 80	Ceepryn
0	510,000	195,000	280,000
10	530,000	200,000	300,000
25	530,000	215,000	196,000
50	480,000	160,000	60,000
100	630,000	185,000	1,000

Effect on Coliform Numbers During Sewage Sedimentation

Results of experiments conducted to determine the effect of the three types of detergents in quantities of 10 to 100 p.p.m. on the number of coliform organisms after settling of sewage for 1 hr. are briefly summarized in Table III. Nacconol N.R. and Tween 80 revealed no bactericidal or reducing effect on the Gram-negative coliform organisms. The anionic agent caused some dispersion of the organisms in high concentrations, whereas the action of the nonionic agent ranged from dispersion in low concentration to agglomeration in the higher amounts. Ceepryn manifested a marked decrease in the number of organisms after settling, especially with the larger quantities of the detergent.

The bactericidal activity of Ceepryn accounts for a substantial reduction in the organisms, while an agglomerative effect of this cationic agent may play a minor role.

Effect on Chlorination of Sewage

An investigation of the influence of detergents on sewage chlorination included the use of the three representative type detergents in concentrations of 10 to 100 p.p.m., as well as chlorination of sewage for satisfaction of 50 per cent of the demand with contact periods of 10 and 30 min.

The presence of Nacconol N.R. and Tween 80 exhibited no increase in kill of coliforms by chlorine. A small and nonuniform inhibition of the chlorine kill was indicated with Nacconol, whereas a general decrease in kill was observed in sewage containing Tween 80.

Some of the results necessary to illustrate the conclusions reached are given in Table IV. No appreciable effect was produced by cationic Ceepryn on the reduction of coliform organisms by chlorine during a 10-min. contact period, but with a longer contact time a substantial reduction in the numbers of coliforms was produced. This action is attributed to the additive effect of the detergent's toxicity to the diminution by chlorination.

Effect on Filtration of Fresh Solids

One method for the treatment of fresh solids has been chemical conditioning followed by vacuum filtration.

TABLE IV.—Effect of Detergents on Coliform Reduction by Sewage Chlorination

Detergent (p.p.m.)	Organisms Per Ml. Remaining[1]					
	Nacconol N.R.		Tween 80		Ceepryn	
	10 Min.	30 Min.	10 Min.	30 Min.	10 Min.	30 Min.
0	323,500	99,000	135,000	77,000	199,000	118,500
0+Cl_2	220,000	91,000	2,000	2,150	125,000	21,800
10+Cl_2	300,000	104,000	1,010	15,500	148,000	13,200
25+Cl_2	242,000	114,000	1,920	7,400	129,000	7,000
50+Cl_2	226,000	97,000	4,800	5,100	120,000	3,100
100+Cl_2	232,000	102,000	3,230	5,000	102,000	2,700

[1] After contact time specified.

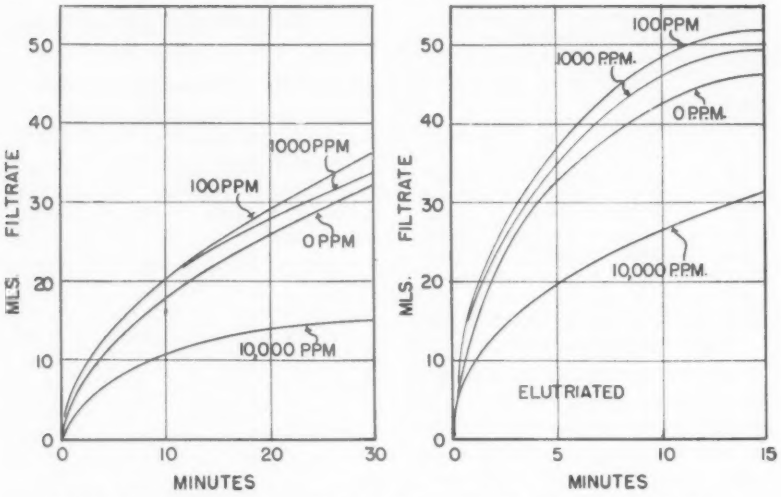

FIGURE 7.—Effect of Nacconol N.R. on dewatering of fresh solids with and without elutriation.

Experiments conducted to determine the effect of the three types of detergents in widely varying concentrations of 100 to 10,000 p.p.m. on the filtration rate of fresh solids show that Nacconol N.R. (Figure 7) and Tween 80 (Figure 8) in concentrations of 100 p.p.m. effected an improvement of the filtration, whereas at concentrations of 10,000 p.p.m. the filtration was impaired.

The action of Ceepryn differed from that of the anionic and nonionic agents.

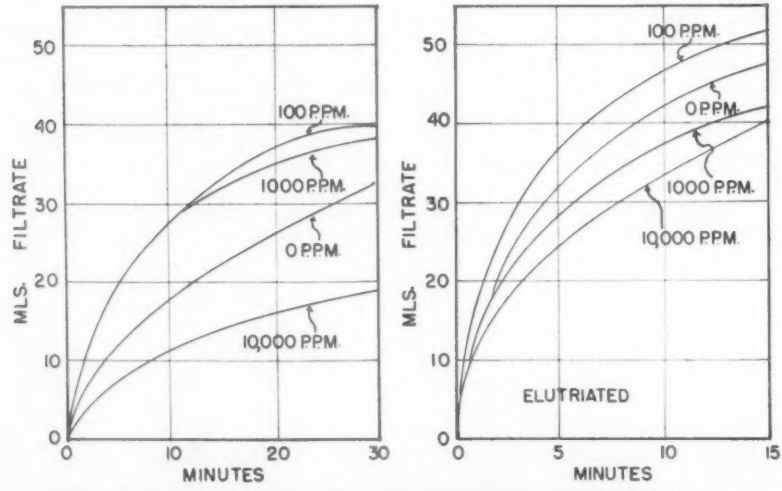

FIGURE 8.—Effect of Tween 80 on the filtration rate of fresh solids with and without elutriation.

All three concentrations of Ceepyrn provided improved and virtually equal filtration rates (Figure 9).

Elutriation of the fresh solids enhanced the filtration by shortening the required time, but did not alter the general trend produced by the detergents.

Effect on Aeration of Water

A preliminary approach in studying the effect of detergents on stream reaeration, oxygen transfer in biological units, and efficiency of oxygen absorption in the activated sludge process includes an examination of the action of detergents on oxygen dissolution in deaerated distilled water.

During a series of experiments it was observed that under quiescent conditions the presence of 50 p.p.m. of Nacconol N.R. did not hamper the absorption of oxygen, but rather caused an increase in the reaeration rate. A soap (Ivory Snow), in concentration of 50 p.p.m., exhibited the same pattern until approximately the fourth day, when the deoxygenating effect of biological oxidation exceeded reaeration and a decrease in dissolved oxygen content was evident (Figure 10).

When air was introduced by the bubbling method under controlled conditions, it was found that the presence of 50 p.p.m. of Nacconol N.R., as well as the same amount of Ivory Snow, depressed the dissolution of oxygen by water (Figure 11).

The diffusional resistance and thickness of nonconvecting liquid films control the rate of absorption of oxygen in water. The thickness of this liquid film under quiescent conditions is many

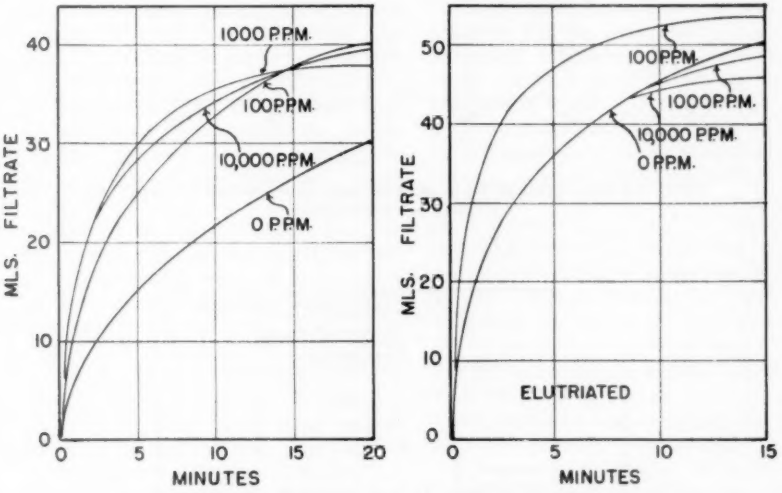

FIGURE 9.—Effect of Ceepryn on the filtration rate of fresh solids.

times greater than that surrounding an air bubble. The presence of a detergent in the air-liquid interface of the bubble may interfere with the diffusion of oxygen into water by (a) exerting a direct resistive action and (b) diminishing turbulence around the ascending bubble and permitting a greater thickness of the liquid film with consequent increase in resistance to gas diffusion. It appears that any resistive effect of detergent molecules in the relatively thick liquid film under quiescent conditions would be negligible. However, the lowering of surface tension of the

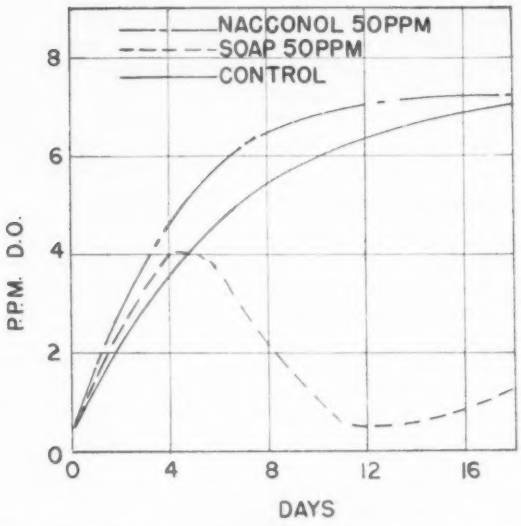

FIGURE 10.—Effect of Nacconol and soap on reaeration of water under quiescent conditions.

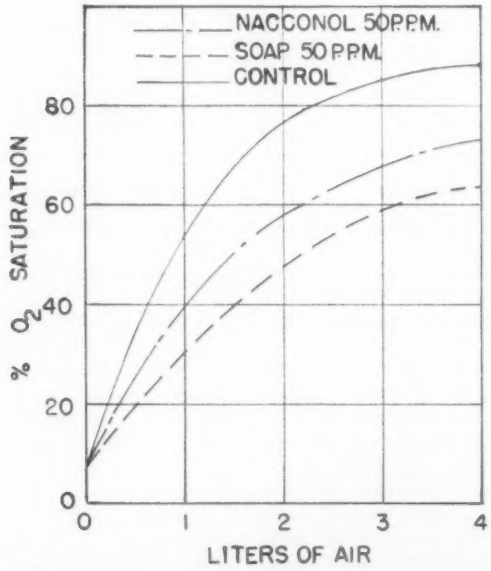

FIGURE 11.—Effect of surface active compounds on reaeration of water by bubbling.

water may decrease the resistance to diffusion of gaseous solute. Thus, the presence of a surface active agent may decrease the efficiency of aeration in certain biological units where aeration by compressed air is employed.

Discussion

With the production of detergents reaching the 1,500,000,000-lb. level and with the widespread usage of these agents, the possible effects of detergents on sewage treatment can no longer be considered as a strictly local problem. The varied effects on sewage treatment devices caused by synthetic detergents depend not only on the quantities of these agents present, but also on the type of compound employed.

The widely used anionic and nonionic surface active agents, in quantities anticipated in sewage, manifest no pronounced adverse effect on sewage oxidation itself or on the oxidation of sewage by activated sludge. The cationic type, with a more limited and specific application, exhibits suppression of such oxidations. In general, some decrease in the efficiency of the direct air method of activated sludge may be expected. In addition, the nuisance of froth production, with the possible deposition of wind-blown froth outside the aeration and settling tanks, should be considered. However, methods to alleviate such nuisance without materially affecting the efficiency of aeration and settling units may be found.

No serious problems in relation to sludge digestion units are induced by the presence of the three representative synthetic detergents. However, a decrease in gas production can be expected if the the detergents replace material quantities of digestible and gas-producing soap compounds.

The individual and varying degrees of influence of different and specific detergents are emphasized by their effects on the chemical coagulation of sewage. The over-all and general adverse effects of detergents on the chemical coagulation of sewage display a similar trend; namely, an increase in effluent turbidity, a decrease in B.O.D. removals, and a lengthening of floc formation time accompanied by lessening of floc size. An increase in the coagulant dosage alleviates the interference caused by the anionic agent, but this increases cost. The presence of the cationic detergent results in a higher degree of purification with low coagulant dosage, or in other words, this type of agent lowers coagulant requirement, hence lowers cost. In general, chemical coagulation of sewage remains feasible and practicable for treatment of sewage containing synthetic detergents, but may be more difficult.

Examination of the general effects of detergents on coliform organisms during settling and chlorination of sewage shows that the anionic and nonionic detergents, in quantities expected in sewage, have no marked effect on the numbers of coliform organisms present in the effluent after settling and no beneficial action on the bactericidal efficiency of chlorine in sewage. The cationic type of agent causes a considerable decrease in the numbers of coliform organisms in the effluent and contributes to sewage chlorination.

Presence of 100 p.p.m. of the three types of detergents aids dewatering of fresh solids. Higher concentration of the more common agents interferes with dewatering. Elutriation of the sludge does not essentially change the trend set forth by the detergents.

General Conclusions

The expected concentrations of the more commonly used detergents are primarily a nuisance in sewage treatment, have minor effects on sewage treatment units and, in general, do not materially affect the degree of purification although some lowering of efficiency may be expected. Special

problems may arise upon discharge of industrial wastes containing large quantities of detergents.

Summary

The tremendous increase in domestic use of synthetic detergents has caused considerable apprehension in respect to their effect upon sewage treatment devices and sewage purification. The effect of the detergents depends upon the concentration and type present in sewage.

In general, the more widely used detergents—anionic and nonionic types—in concentrations expected to be found in sewage, do not appreciably interfere with the oxidation of sewage alone or by activated sludge, whereas the cationic type, used for specialized purposes, retards these oxidations. Displacement of soap by detergents diminishes gas yields from anaerobic sewage sludge digestion without inhibition or retardation of the digestion processes. Anionic and nonionic detergents interfere with chemical coagulation of sewage in terms of purification attained and modification of floc formed, but increase in the dosage of coagulant can alleviate some of these adverse effects. Cationic agents lower the quantities of coagulant required. Cationic detergents markedly decrease the number of coliform organisms during sewage sedimentation and produce an added effect to the bactericidal activity of chlorine. The anionic and nonionic types exhibit no measurable effect in either case. The three types of detergents in concentrations of 100 p.p.m. show an improvement in the dewatering of fresh solids. Elutriation does not essentially disrupt this pattern. Aeration efficiency in activated sludge units may be impaired by surface active compounds.

The concentration and type of detergents expected in sewage are primarily a nuisance without materially affecting the degree of purification. Industrial wastes containing large amounts of specific detergents may cause difficulties in waste treatment.

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MEASUREMENT OF SURFACE TENSION OF SEWAGE

I. Fundamental Considerations

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The fundamental physical phenomenon known as surface tension thus far has appeared only casually in American sewage literature. The need for specific investigation is discussed in an editorial (*Sewage Works Journal*, **20**, 3, 578; May, 1948), which refers to the volume of work being accumulated in Great Britain. Investigation there has been with specific reference to effects of increasing wide-spread domestic and industrial usage of synthetic detergents; a great deal of work has been done at sewage plant laboratories, where considerable emphasis has been on effects of detergents on grease extraction processes. This discloses only one important and basic reason for need of detailed investigation of the surface tension of sewage.

In 1949, at Indianapolis, it was decided to begin a routine investigation of the phenomenon with more general aspects in view, the implications and resultant manifestations of detergents, etc., to follow with increased experience in the course of the study.

What Surface Tension Is

Surface tension and interfacial tension are the terms applied to the phenomena which occur at the interface of two phases, whether either phase is gas, liquid, or solid. The term interfacial tension is properly the universal for reference to any region of discontinuity between two phases, but through common usage it is reserved for the region of contact between two immiscible liquids or a solid and a liquid, and the term surface tension is limited to the region of contact between a solid or liquid and a gas (air, more often than not).

In the consideration of surface tension a force per unit length is found which reduces to dimensions of mass $\times$ time^{-2}. This surface tension is the property which causes a liquid to assume a minimum surface area and is the result of the cohesive forces of the molecules in the liquid. Indeed, it has been demonstrated by many workers (as early as 1873 by Plateau) that if the effect of gravity be eliminated, a small mass of liquid will assume spherical shape. However, as commonly dealt with, liquids are under the effect of gravity and it is their level surface which must be investigated. The molecules in a fluid state are the described source of attraction (force) which causes the surface of a liquid to assume a minimum surface area. This condition of reduction of the surface of a liquid in contact with air is due to the fact that a given molecule in the surface is subjected to forces in every direction, and the magnitude of these forces varies with the direction. The strongest force, since the liquid is the denser phase, is from within the liquid and perpendicular to the surface. It must be remembered that, contrary to the deceptive calm visual appearance of a static body of liquid, at ordinary temperatures there exists a constant energetic state of molecular agitation. Surface molecules are attracted inward at a more rapid rate than others migrate outward to replace them. It is fundamentally this consid-

eration which explains the reduction of area at the surface, the greater attraction inward causing a maximum contraction; that is, until the surface area is at a minimum possible under obvious limitations for a given volume.

The spontaneous contraction of the surface of a liquid is visible evidence of a free energy; therefore, work must be performed to extend a liquid surface, work opposing the attractive (cohesive) force of the internal molecules. Mathematically, surface tension is the substituted hypothetical equivalent of the free surface energy (a correct assumption for practical purposes); the energy per unit area thereby is replaced in thought by the surface tension acting parallel to the surface, and the dimensions are mt^{-2} as previously mentioned. The units of surface tension are, therefore, of energy, or ergs per square centimeter, which reduces to dynes per centimeter, the most commonly used expression.

Capillarity

The history of the study of capillarity is that of the study of surface tension and at least brief mention of capillarity is essential to this discussion. The rise of a liquid in a capillary tube is a hydrostatic pressure measure showing the difference in pressure across the meniscus of the liquid in the tube. The elementary expression for the capillary rise feature is given by

$$\gamma \cos \theta = \tfrac{1}{2} g\, r\, h(D - d) \qquad (1)$$

in which γ is the surface tension, θ is the angle of contact between the liquid and the tube wall, g is the gravitational constant, r is the radius of the tube, h is the height of the column of liquid in the tube, and $D - d$ is the difference in densities of the liquid rising in the tube and the surrounding medium.

Because of the frequency of reference in the literature to the unique quantity called the capillary constant, it is deemed necessary briefly to define it here. When $\theta = 0$, Eq. 1 may be written

$$\frac{2}{g(D - d)} = r\, h = a^2 \qquad (2)$$

in which a^2 $(= r\ h)$ is the capillary constant. The origin is apparently somewhere in the early history of the study, wherein one of the first observations was that the radius of the capillary tube times the height of rise of the liquid was very nearly constant. The square root of this quantity, a, has been found important to many calculations of surface tension, as is shown later.

Adsorption

Because sewage is composed of many different classes of molecules, each differing in intensity of field of force, it is conceivably among the most difficult materials to measure with respect to surface tension. Mention of the property of adsorption should not be neglected in any discussion of sewage surface tension. Adsorption refers to the concentration of a constituent at the surface. An increase in concentration at the surface is called positive adsorption; a decrease is called negative adsorption. Qualitatively, when the surface tension of the solution is less than that of the solvent, a concentration of the solute at the surface is the rule; if the solution has a larger tension, then the solute is strongly attracted inward. It may be shown that addition of solute will reduce the surface tension of a liquid because the solute may concentrate in the surface; however, it is difficult to increase the surface tension by addition of solute when it is contained principally within the solution where it cannot affect the surface. To verify this, simply reflect that many larger organic molecules can reduce the surface tension of water to approximately 25 dynes per cm. (showing positive adsorption wherein the surface would be composed largely of, for example, long-chain hydrocarbons), whereas inor-

ganic salts (negatively adsorbed) may raise the surface tension, in strong solution, by only a few dynes per cm.

Quantitatively, Gibbs offered the first thermodynamic deduction of the relationship between surface tension change and the degree of adsorption, which is expressed as

$$\mu = \frac{C}{R\,T}\frac{d\gamma}{dC} \qquad (3)$$

in which μ is the excess of solute in the surface phase (per square centimeter of surface) and $d\gamma/dC$ is the rate of change of surface tension with concentration. Adam (1) interprets the proof of Gibbs and shows the proof of Guggenheim very clearly, using free energy relations. The exact derivations are demonstrated generously in the literature and it is needless to repeat them here.

It is but in accordance with the basic principles of thermodynamics that a liquid assumes a minimum surface area and that when this minimum surface is presented, a minimum of surface free energy is related to the mass of the liquid. Some important thermodynamic relations are given by Harkins (2) with respect to entropy, latent heat, and general statements of energy changes, which should be consulted for elucidation and appreciation of the subject.

It is important to investigate certain other physical properties of liquids which show an interrelationship with surface tension, but it is beyond the scope of this paper to discuss all of the known remarkable manifestations of molecular activity at the surface of a liquid. It must suffice to consider one of the aspects, surface tension, as real and as having real dimensions. Further mention of the fundamental considerations of surface tension is not possible in the limited space allotted inasmuch as methods of measurement and their limitations are more pertinent to the discussion.

Measuring Methods

Categorically, surface tension measuring may be divided into dynamic and static methods. The dynamic methods, which are not sufficiently developed at present for practical use, include determining the wave lengths of ripples, oscillations of hanging drops, etc. In the case of solutions where the surface is continually being renewed, preventing adsorption from attaining equilibrium, values by means of dynamic methods would not be comparable to those obtained by static methods.

Static methods are applied to stationary surfaces and are fundamentally founded on either a hydrostatic pressure principle or upon a film formation and the extension of the liquid by means of a device or support to which the liquid adheres. Of the former principle, examples are the capillary height, drop weight, bubble pressure, hanging drop, and sessile bubble or drop methods; the plate methods and ring methods exemplify the second principle of static method of surface tension measurement. Of all these methods mentioned, only three lend themselves satisfactorily when the measurement involves solutions (as opposed to pure liquids); specifically, the drop weight, sessile bubble or drop, and ring methods. Of these, the ring method may be slightly less accurate except where time effects are involved (as in the case of sewage colloids), and then, by elimination, it becomes the only practical applicable method. Of course, each method has its proper and often ideal application and no single method is ideally suited to all conditions. However, the ring method, with its inherent facility, seems best suited to measurements involving sewage.

Before entering into details of the ring method, however, it is necessary to make a few general reflections regarding measurement. Admitting that the measurement of surface tension

is basically an elementary problem, Harkins (2) quite correctly refers to the history of the various methods used as a "comedy of errors"; however, numerous additional sources of error introduced by the very nature of sewage amplify the comedy to an almost absurdity. Because of this nature of sewage which is neither pure liquid nor solution, but a heterogeneous mixture of substances in true solution, colloidal solution, suspensions, etc., it is difficult, if not almost impossible, to obtain reproducible values to the extent known for pure liquids, but a value can evolve which is subject to the fundamental principles of surface tension. The heterogeneity and lack of stability and uniformity of combined domestic and industrial wastes probably account for the discouragement of many workers in the investigation of this surface tension and thus probably accounts for the lack of data.

Sources of error in the measurement of surface tension are many, but the remarks here will be confined to those concerned with the ring method as this method is the only one considered satisfactory for sewage. The ring method itself had an unfortunate early history, in that, due to error in theory, prior to about 1926, extremely erroneous results were obtained. Earlier ideas purported that the maximum pull, P, per centimeter on a ring was equal to the surface tension. The erroneous equation was

$$P = M\,g = 4\pi\,R\,p = 4\pi\,R\,\gamma \quad (4)$$

where P is the total maximum pull on the ring (as determined by an analytical balance) and $p = P/(4\pi R)$. Results were often as much as 30 per cent high for surface tension on this assumption.

The pull, P (due to the weight of the column of liquid raised by the ring), as noted by Harkins (2) is dependent on the shape, S, of the inner and outer surfaces raised by the ring. The angle of contact would affect these surfaces, but in the case of properly cleaned rings this angle has always been found to be zero.

The principle of similitude (the neglect of which was a fundamental source of error in early applications of the ring method) was applied by Harkins, Young, and Cheng (3) to correct the theory. Their finding was that according to the principle of similitude (a relation of general dimensional theory regarding shape), the shape of a meniscus depends upon R/a (or R^3/V) alone and not its size. Here R is the radius of the ring (to the center of the circular wire), a is the square root of the capillary constant as previously discussed, and V is the volume of liquid raised by the ring.

The principle of similitude as applied to the ring method implies simply that the shape of the surface supported by the pull of the ring under static conditions depends upon several dimensionless variables, the two most important of which are: the ratio of the cube of the radius of the ring to the volume of liquid upheld (R^3/V), and the ratio of the radius of the ring to the radius of the circular wire (R/r). Hence, if the shape, S, is a function of these variables,

$$S = f(R^3/V,\ R/r) \quad (5)$$

and if the surface tension is a function of the shape—that is,

$$\gamma = \frac{M\,g}{4\pi R} \cdot f(R^3/V,\ R/r) \quad (6)$$

—then the correct equation is

$$\gamma = \frac{M\,g}{4\pi R} \cdot \frac{\gamma}{p} = \frac{M\,g}{4\pi R} F \quad (7)$$

in which F $\left(\text{or } \frac{\gamma}{p}\right)$ is the correction factor.

The values of F, given in a monumental work by Harkins and Jordan (4), were obtained by using accurate surface tension values determined by the capillary height method or drop

weight method and comparing with the values of p in the last equation above. The materials used for a basis of comparison in the preceding were water, benzene, and bromobenzene, chosen for their purity and relative stability under conditions of measurement. Correction curves are shown by these authors for a given R^3/V by plotting R/r against γ/p.

A further source of obtaining values of F as found by Harkins and Jordan is from calculations in accordance with a theory proposed by Freud and Freud (5). These authors, in a precise mathematical presentation, offer an equation which gives data describing the shapes of the surfaces which are formed by the ring raised out of a liquid surface, which data, they state, may be used to supplement the tables of Bashforth and Adams. The fundamental work of Bashforth and Adams is rare and somewhat difficult to obtain; however, numerous publications after 1921 give the necessary data in addition to a wealth of supplemental information.

With respect to the use of the du-Noüy tensiometer, Zuidema and Waters (6) published a later work giving correction factors according to their formula and offered curves for rings of different R/r wherein $P/(D-d)$ is plotted against the correction factor F.

Numerous precautions are essential to adherence to theory and practice of use of the ring method. A significant error occurs when the plane of the ring is not horizontal. Harkins and Jordan (4) disclosed that this error is proportional to the square of the angle and offer the equation

$$-\Delta p = k\,a^2$$

which holds for angles less than 1.5°. The value of k is given as 0.36. The magnitude of this error becomes obvious from their data; for example, for an angle of 0.47° the error is 0.1 per cent, and for an angle of 1° an error of 0.43 per cent is found.

Another fundamental and obvious requirement for the use of the ring is that the wire of the ring must be in one plane. It has been found that a low value results when this condition is not met.

It is necessary that a relatively large area of liquid surface be used in order to avoid any effect imparted by curvature of free surface upon the important shape of the surfaces raised by the ring. Various authors have reported on diameter requirements of the sample vessel and it is generally concluded that the diameter should be in excess of 8 cm.

Evaporation and the resultant cooling of the large surface relative to the interior of the liquid, in addition to the strong possibility of altering the very nature of the surface in the case of colloids, etc., affords another cause of error. A modified funnel covering the sample being measured serves to reduce the possibility of this error, but for extremely accurate work it is considered necessary to enclose the entire system in a thermostat. A specially designed flask to accomplish this is shown by Harkins and Jordan (4).

That the ring itself must be free of all motion except for its very slow upward motion is another obvious requirement of its application. The surface of the liquid must be absolutely free of all externally induced wave motion. This type of motion is readily found in ordinary methods where vibrations from movements of the apparatus impart such waves to the liquid. Harkins and Jordan (4) describe a specially designed arrangement in connection with using an analytical balance which involves the use of a jack to elevate and lower the balance and apparatus, keeping the sample stationary and thus avoiding vibratory translations. Such a means is desirable for work of high accuracy, but is not easily achieved in an ordinary laboratory. With respect to the commercial duNoüy tensiometer, the supplied instrument is quite capable of transmitting serious vibrations. A

number of simple modifications are possible to reduce this feature. It is more desirable to raise the instrument (and ring) rather than lower the sample as is indicated by the basic design of the instrument. Harkins (2) suggests that a special jack be constructed to raise the entire tensiometer and that the sample vessel be on a stationary support. Another means of accomplishing this, which is under investigation at Indianapolis, is to replace the entire supporting column (pillar) of the tensiometer with a specially designed simple hydraulic jack consisting of a long piston and cylinder having a relatively short stroke.

As regards the less desirable alternative, lowering the sample, the platform lowering device as supplied may be modified and improved simply by replacing the piston which supports the sample table with a piston of greater length compared to its diameter. At Indianapolis this was accomplished at the sewage plant machine shop by building up the manufactured piece with silver solder and machining it down to the proper size. The supplied piston is actually about $^3/_{16}$ in. long and it was increased to about $^9/_{16}$ in. by the described modification. Much smoother operation was observed as a result of this change. Another method of gently lowering the sample which occurred independently to this author, but is also suggested by Harkins (2), is that of floating the sample vessel on mercury and gradually discharging the mercury to attain a steady lowering of the sample. Another suggestion for somewhat smoother lowering of the sample involves the use of a microscope stand adjustment device. Thus, with certain precautions, a Cenco precision model duNoüy tensiometer may be used to obtain results of reasonable accuracy. This is especially true and suitable for sewage, where the primary concern is measuring relative changes in surface tension rather than the establishing of absolute values.

In addition to the above precautions, the procedure in the laboratory at Indianapolis includes other indicated policies. The first step preparatory to measuring the surface tension of a sample is thorough cleaning of the vessel (pyrex dishes 9 to 10 cm. in diameter are used) which will contain the sample. Potassium dichromate-sulfuric acid cleaning solution is used, followed by complete rinsing with distilled water and then careful drying. The instrument used for the bulk of the measurements is a Cenco "precision model" duNoüy tensiometer, which, along with the sample table, next must be leveled. The platinum-irridium ring (mean circumference 4 cm.) is cleaned in a flame and then suspended properly on the tensiometer. A polished metal mirror serves as accessory surface on the sample table and the ring is lowered as close as possible to this without touching it. This procedure facilitates verifying the horizontal plane of the circular wire of the ring (a serious source of error previously mentioned). By using the ring and its close mirror image, adjustment is made, if necessary, to make the ring apparently horizontal. The ring is then raised to make room for the sample dish, which is next put in place on the sample table. The temperature of the sample is noted at this time. The ring is then lowered into the surface of the liquid and the index of the ring support is set with respect to zero position. The actual measurement then proceeds by very slowly raising the ring by means of increasing the torsion of the wire, keeping the index of the arm at zero. The slow, steady, increasing pull is continued until the ring sharply separates from the liquid and a reading of the instrument venier scale is then made and noted as the apparent surface tension. It is important to note that in filling the sample dish an excess is used to overflow the dish in order to wash away the relatively large particles, such as grease, which might ad-

here to the ring and thus give it a false additional weight.

Detailed description of the tensiometer and its manipulation is avoided, inasmuch as such may be obtained readily from the Central Scientific Company, Chicago, Ill. Satisfactory rings may be obtained from this company of which measurements have been made and the value of the ratio R/r given for each, thus sparing the user a difficult task.

Certain inconvenient refinements of application of the ring method are not included in the routine technique at Indianapolis, as this would defeat part of the purpose of the project; specifically, to determine the feasibility of a relatively simple and convenient method of determining surface tension values available to most sewage plant laboratories. That is, a method is desired which will give reliable values and yet possess almost routine simplicity in its technique. The experience of approximately two years at Indianapolis is relatively brief, but it would appear from replicate data and occasional verifying with an analytical balance that the duNoüy tensiometer is satisfactory for the purpose.

In the actual measurements by the ring method (by tensiometer) attempts were made to determine the degree of reproducibility of a given value for a given sample; disagreement of more than 2 per cent frequently occurred from what was considered careful technique. The already mentioned falacies in method accounted for part of the error and the remainder was thought to be due solely to the nature of sewage. The margin of error due to this source was reduced considerably upon the realization that not sufficient time of quiescence had been allowed to permit the surface of a sewage sample to come to a state of "equilibrium." By allowing only a brief time after placing the sample on the table before commencing measuring, a "dynamic" surface tension was actually measured. A constant or reproducible value as such would be extremely difficult, because sewage is composed of a great variety of molecules having different densities. When the sample is freshly transferred to the dish there is no separation of these different molecules and an unstable surface is presented. If a constant value is sought for sewage or any heterogeneous mixture, it must be obtained as a true static surface tension. This may be accomplished by allowing the sample to stand in readiness for measurement for approximately 1 hr.; then it is certain that stratification and separation of the substances of different densities, etc., is affected and that adsorption should be stable to the extent that it is then possible to obtain the desired static or constant surface tension. It is this value which permits verifying technique. Many difficulties encountered in the measurement of solutions in general, with particular reference to surface-active substances, may be found in a published work by Hauser (7) and another by Fischer and Gans (8).

It is unfortunate to these determinations that lack of knowledge of adsorption does not permit any assurance of the temporal relationship between the measurement of the surface tension and the formation of the surface representing the constituents of the entire liquid medium. Since recently formed surfaces are the continual nature of sewage under treatment, it is this surface tension which is met in practice and should be exploited in investigation in the laboratory.

In the early investigations at Indianapolis it is interesting to note that a 2 per cent error did not apparently render a serious determent to the preliminary investigation of trends in sewage. Changes observed were generally of a greater magnitude than 2 per cent, which permitted establishment of such change trends as daily changes, hourly changes, changes as the result of the deliberate addition of surface actants,

etc. Usually such changes are more than several dynes per centimeter.

In a subsequent paper results of measurement of surface tension at Indianapolis are to be presented. The implications of changes in surface tention of sewage will be discussed with this presentation of data.

Summary

1. Surface tension is a real value of the dimensions mt^{-2} which is the result of an unbalance of cohesive forces at the surface of a liquid. The surface of a liquid assumes the minimum area possible in accord with the laws of thermodynamics.

2. The ring method, with theory corrections to include the principle of similitude, is best suited to the measurement of the surface tension of sewage.

3. Certain mechanical precautions are necessary for reliable results with the ring method, the more important of which are: (*a*) the ring must lie in one plane and be horizontal, (*b*) a relatively large area (diameter at least 8 cm.) of surface of sample must be used, and (*c*) there should be no vibration imparted to the liquid being measured.

4. Extreme care must be taken in use of the duNoüy tensiometer and certain modifications are desirable for increased accuracy.

5. A "dynamic" surface tension value is obtained when measurement is made briefly after any mixing of the sewage sample while a mixed dispersion of different molecules exists in the surface. After about 1 hr. sufficient stratification and adsorption probably has occurred to permit of more constant measurable values of surface tension of the sewage.

6. In the study of change trends an error of reproducibility of 2 per cent appreciably did not affect the investigation of sewage surface tension.

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AEROBIC BIOLOGICAL STABILIZATION OF ORGANIC SUBSTRATES

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The employment of submerged, aerobic, biological sewage treatment systems has resulted in the attainment of a wide range in the efficiency of stabilization of organic substrates. Insufficient attention has been given to the development of a rational loading parameter for such systems, although many loading parameters of an empirical nature have been employed in attempts to relate efficiency of stabilization of putrescible matter to controllable design features. Parameters that have been used for the design and operation of the activated sludge process include: B.O.D. values of the influent sewage, detention periods, mixed liquor concentrations, air quantities, physical properties of the sludge, and relative aeration tank dimensions, either singly or in combinations with each other.

Undoubtedly some of the foregoing factors are of major importance in reducing the pollutional load of a treated water-borne waste. Laboratory and plant-scale investigations have disclosed the qualitative relations which exist between a few of these parameters and the efficiency of B.O.D. removal, but a functional loading parameter for the design and operation of submerged, aerobic, biological sewage treatment systems still remains to be established. It is the intent of this study to investigate the reliability of one such parameter and to extend its application over the entire spectrum of normal sewage treatment efficiencies.

There are at least six factors which have been reported as having an effect upon the efficiency of such systems. Unfortunately, most studies into these factors have been concerned only with the activated sludge process. For this reason, the references in this paper pertain essentially to observations obtained from that process.

The influential factors may be grouped into one of the following categories: (a) pollutional matter applied in terms of its rate of flow and concentration (1)(9)(18)(19)(20)(24)(25); (b) type and character of pollutional matter (2)(24); (c) period of aeration (2)(4)(16)(24); (d) solids concentration in the aeration chamber (4)(5)(8)(24); (e) quantity of dissolved oxygen available to the sludge (7)(11)(24)(27); and (f) other factors, such as pH (5)(14)(17)(22), temperature (12)(13)(23)(26), volatile matter present in the sludge (5)(21)(28), and sludge age (15). If the effect of toxic materials (included in item b) are eliminated, the factors indicated as items (a), (c), and (d) have been shown to exert the greatest influence on the efficiency of B.O.D. removal.

Development of a Rational Loading Parameter

Harris, Cockburn, and Anderson (10) were the first to propose the combination of the three major factors into a loading parameter applicable to the activated sludge process. They evaluated a parameter in terms of the strength of applied sewage, the per-

* The investigations reported in this paper were conducted in part while the author was Teaching Fellow, Graduate School of Arts and Sciences, Harvard University.

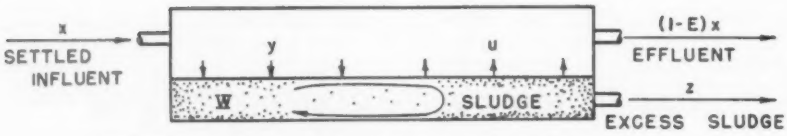

FIGURE 1.—Mathematical model of the activated sludge process.

centage of sludge, and the period of aeration.

The N.R.C. Sub-Committee on Military Sewage Treatment (19) related the efficiency of B.O.D. removal by 12 municipal and 5 military activated sludge plants to a loading parameter expressed as pounds of 5-day B.O.D. applied daily per 1,000 lb. of suspended solids in the aeration tank per hour of aeration. The report likewise established a loading parameter for contact aeration plants. This parameter was given as pounds of 5-day B.O.D. applied daily per 1,000 sq. ft. of contact surface per hour of aeration.

Okun (21) applied a similar type of loading parameter to his results from bio-precipitation studies and found that a parameter of the form pounds of B.O.D. applied daily per 1,000 lb. of volatile solids per hour of aeration correlated reasonably well with the efficiency of B.O.D. removal.

However, the basis of such loading parameters was not rationalized until Fair and Thomas (6) presented their studies. In developing a mathematical model of the activated sludge process, they have assumed continuous-flow conditions analogous to those existing in a conventional activated sludge plant. In its fundamental form, this model may be illustrated by Figure 1. They defined the various terms as follows:

x = weight of putrescible matter, in pounds per day, in the incoming settled sewage.

y = net weight of putrescible matter, in pounds per day, transferred to the sludge phase.

W = total weight of sludge, in pounds, within the system.

u = that daily portion of W (lb. per day) which is decomposed and released to the supernatant or to the atmosphere in the form of oxidized end products (water, carbon dioxide, nitrate-nitrogen, and sulfates).

z = that daily portion of W (lb. per day) which is wasted as excess activated sludge.

$E = y/x$ = the efficiency of the activated sludge process in removing putrescible matter, expressed as a proportion.

In this system a steady state has been assumed to exist when each of these factors remains substantially constant. Using the equations of continuity resulting from the conditions established for the mathematical model, Fair and Thomas obtained a generalized relation of the following form:

$$E = \frac{100}{1 + a X^b} \qquad (1)$$

in which X is the loading parameter expressed as pounds of 5-day B.O.D. applied daily per 1,000 lb. of suspended solids per hour of aeration, E is the per cent efficiency of B.O.D. removal, and a and b are constants.

The experimental apparatus used in the author's work was designed to conform with the conditions of equilibrium similar to those which Fair and Thomas assumed in their analysis.

Characteristics of the Synthetic Sewage Used

The requirements of steady-state conditions necessitated the use of an organic substrate which would permit replicate operations. In sewage research domestic sewage is usually employed as the source of bacterial food, but variation in strength and composition is a marked characteristic of water-

borne wastes. Consequently, it became necessary to utilize a reproducible synthetic sewage which would compare favorably with domestic sewage in regard to rate and quantity of oxygen demand.

The synthetic mixture used in this study was compounded as a concentrate containing the ingredients listed in Table I.

Five B.O.D. runs on 4 separate batches of concentrate yielded an average first-order rate constant of 0.22 per day (range 0.21 to 0.24 per day) and an average ultimate demand of 107,000 p.p.m. (range 103,000 to 113,000 p.p.m.) The average lag period was 0.83 days (range 0.80 to 0.89 days). Figure 2 graphically illustrates the course of a typical B.O.D. reaction of the concentrate.

Sewage strengths of approximately 50, 100, and 200 p.p.m. 5-day B.O.D. were used for the contact aerator experiments. These strengths were obtained by proper dilution of the concentrate with Cambridge (Mass.) tap water. An analysis of the B.O.D. results of 57 observations on the low-strength sewage yielded an average B.O.D. of $53.0 \pm 3.88/\sqrt{n}$ p.p.m. The average for the intermediate-strength sewage was $95.3 \pm 6.31/\sqrt{n}$ p.p.m., based on 98 observations, and the high-strength sewage gave an average of $203 \pm 11.4/\sqrt{n}$ p.p.m. from 41 observations. The ratios of the standard deviations to the means were 7.3, 6.6, and 5.6 per cent, respectively.

TABLE I.—Formula for the Concentrated Synthetic Sewage

Ingredient	Amount (g./l.)
Skim milk	48.0
Peptone	48.0
Gelatin	16.0
Soluble starch	32.0
Urea	8.0
Disodium hydrogen phosphate	8.0
Potassium chloride	1.12
Calcium chloride	1.12
Magnesium sulfate	0.80
Ferric sulfate	0.80

Laboratory Studies

In order to satisfy the conditions of steady state, three factors were con-

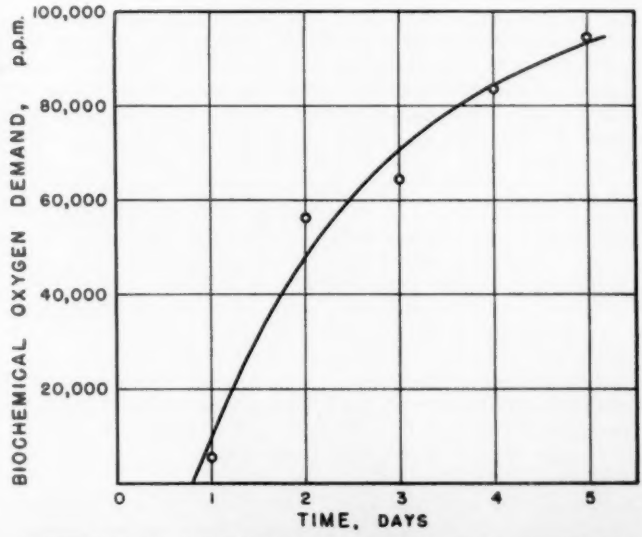

FIGURE 2.—Typical B.O.D. data of synthetic sewage concentrate.

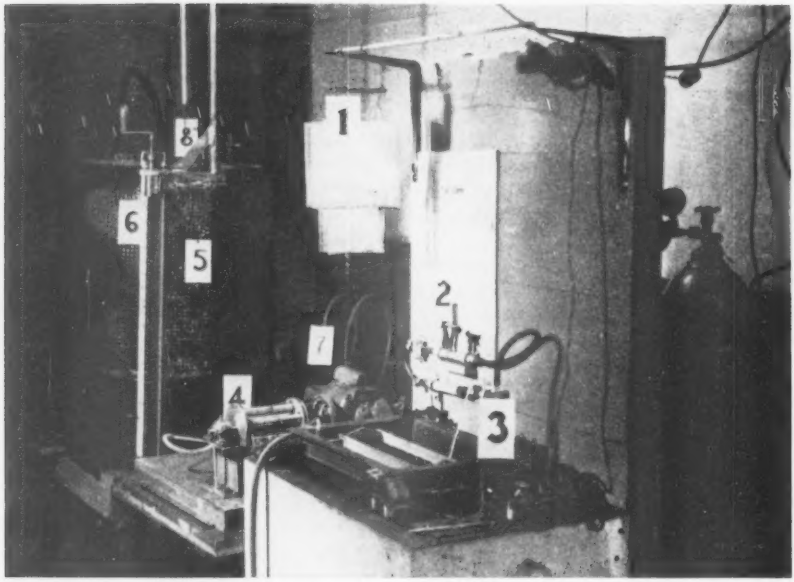

FIGURE 3.—Experimental apparatus showing: (1) clean contact plates, (2) air measuring device, (3) contact aeration chamber, (4) pump, (5) insulated storage tank, (6) storage tank volume measuring device, and (7) refrigerator.

trolled as closely as possible. These were: (a) a uniform application of the organic feed to the system; (b) a constant time of contact between the sewage-sludge mixture within the system; and (c) a uniform rate of sludge production and wastage. The design of the experimental apparatus was based upon these requirements.

Experimental Apparatus

The experimental apparatus consisted of: (a) a storage tank for mixing and preserving the synthetic sewage; (b) a pump for applying the synthetic sewage at a uniform rate; (c) a contact aeration tank, in which the biochemical system was maintained; (d) contact surfaces, upon which the sludge growths were promoted; and (e) an air supply. A general view of the experimental apparatus is shown in Figure 3. Figure 4 illustrates the apparatus schematically.

Refrigeration was decided upon as the most practical method of preserving the synthetic sewage. The mixture was prepared by diluting an aliquot portion of the sterilized concentrate with tap water in the refrigerated storage tank. The refrigerator was adjusted so that the temperature of the mixture was reduced to and held at about 1° C. Bacterial growths in the storage tank were further minimized by removing the tank from service about once per week and chlorinating with a solution of hypochlorite. An analysis of 80 pairs of B.O.D. tests upon samples taken immediately after a fresh mixture was prepared and again shortly before the mixture was depleted revealed no significant variation in the sewage strength from the beginning to the end of each day's operation.

The synthetic sewage mixture was pumped from the storage tank by a

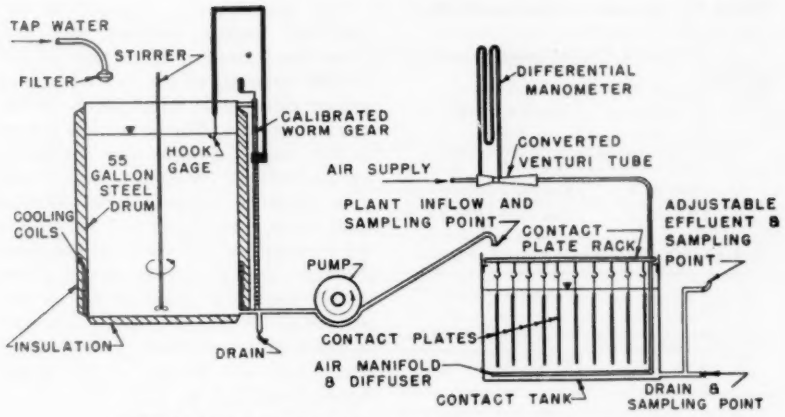

FIGURE 4.—Schematic diagram of the experimental apparatus.

Harvard pump (20). The contact aeration tank consisted of a porcelain-enamel-coated steel tank 11 in. by 16 in. in plan and 18 in. in over-all depth. The tank had a semi-cylindrical bottom, which minimized dead spots in the mixed liquor circulation. The tank was partially immersed in a constant-temperature water bath, which held the temperature of the tank contents at 25° ±0.12° C.

The contact aeration system was used in these experiments to obtain a more precise measure of the weight of sludge involved. A 20-mesh stainless steel screen was the material selected for the contact surfaces. Tests on a series of different materials indicated that the

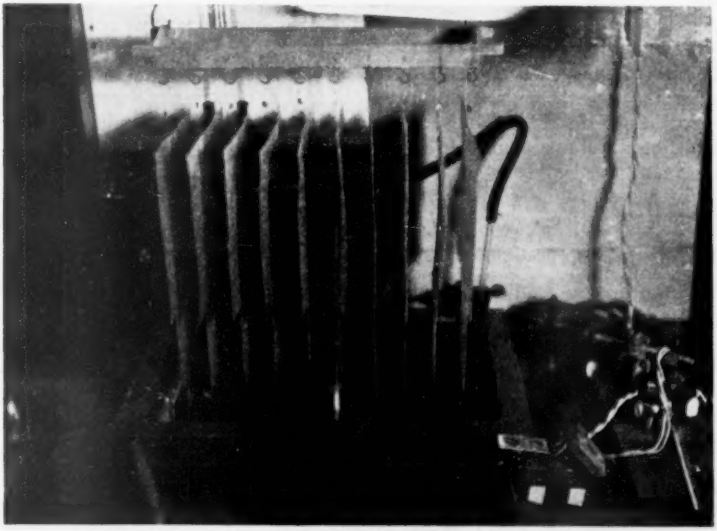

FIGURE 5.—Detailed view of contact plates and plate rack.

TABLE II.—Schedule of Experimental Runs

Approx. Detention Period (hr.)	Approx. Synthetic Sewage Strength, 5-Day B.O.D.		
	50 p.p.m.	100 p.p.m.	200 p.p.m.
(a) Contact Plates Removed Every Day			
2	Run No. 8	Run No. 9	Run No. 10
4	Run Nos. 3A, 3B	Run No. 2	Run No. 4
8	Run No. 5	Run No. 6	Run No. 7
(b) Contact Plates Removed Every Second Day			
4	—	Run No. 11	—
(c) Contact Plates Removed Every Third Day			
4	—	Run No. 12	—

sludge developed most readily on the screen. The sludge could then be removed with the screen and measured by direct weighing. A system of plate removal and replacement was formulated so that 4 plates were removed and replaced daily by clean plates, the weight of sludge on the plates removed furnishing a measure of the sludge remaining on the 6 plates not removed. Each plate contained 0.69 sq. ft. of screen. Figure 5 shows the contact plates after removal from the contact aerator.

The air supply was measured by passing the gas through a calibrated meter as shown in Figure 4.

The liquid volume contained in the contact tank was held constant at about 34 l. by means of an effluent pipe of adjustable elevation.

Operating Procedure

A wide range of loading parameters was obtained by employing three different strengths of sewage at each of three different detention periods. During these nine runs the plate removal schedule was based on a 1-day time interval. Two additional runs were made to investigate the effect of the rate of sludge wastage. The run numbers corresponding to the respective conditions are summarized in Table II.

The approximate strength of the synthetic sewage mixture was predetermined from a knowledge of the B.O.D. strength of the concentrate, a proper dilution of which gave the desired strength. The detention period in the contact aerator was controlled by the rate of pumping. After each plate removal operation the contact tank sides were squeegeed to remove the growths that had developed on these surfaces, and a portion of the mixed liquor was then collected for a suspended solids determination. The sum of the sludge weight on the 10 contact plates and the sludge in the mixed liquor furnished an estimation of the total sludge in the system.

The contact tank was seeded daily with 100 ml. of fresh, filtered domestic sewage.

B.O.D. measurements on the storage tank contents and on the settled contact tank effluent furnished a measure of the plant efficiency.

Samples for D.O. and suspended solids determinations were collected at the contact tank effluent pipe about 10 min. before each plate changing operation. Figure 6 illustrates the data obtained from a typical run.

Analytical Determinations

All determinations were made in accordance with "Standard Methods" (3), except in the estimation of suspended solids. Alundum crucibles were used in lieu of Gooch crucibles.

The solids on the contact plates were determined by drying the plates in an oversized oven under standard conditions of temperature for a 3-hr. time interval. The plates were allowed to cool in a large desiccator before being weighed. All sludge weights reported in this paper are expressed on a dry-weight basis.

Experimental Results

Once the conditions of a given run were established, it became necessary to define a criterion which would indi-

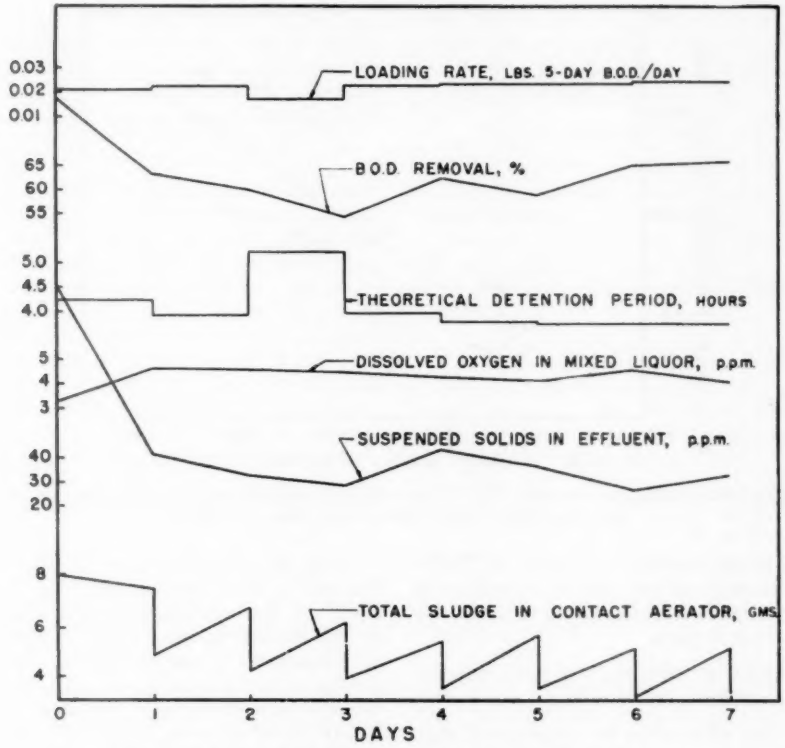

FIGURE 6.—Typical data obtained from one experimental run.

cate that the biological system had reached equilibrium. The B.O.D. test was not suitable, because the results of this test are not known for 5 days after the test is initiated. It was arbitrarily decided that variations of not more than 5 per cent in the total sludge content of the aeration chamber on successive days would satisfy the required condition.

During the initial phases of experimentation, the length of time required for the system to approach equilibrium was not known. Consequently, run No. 2 was conducted for 14 days and run No. 3 for 11 days. Equilibrium was established within 2 to 3 days after the beginning of each experiment. As a result, a 6-day period was established as the minimum time interval necessary for each of the subsequent runs in which the time unit of contact plate removal was 1 day.

The experimental plant was placed in operation on June 20, 1951, and run continuously until October 6, 1951. Upon completion of a given run the conditions required for the next run were established immediately, and whenever the only variation in conditions was a change in the sewage strength, the system attained equilibrium within 3 days or less. This effect was observed in the runs where the B.O.D. of the storage tank mix was doubled.

When the detention period was doubled and the applied B.O.D. load

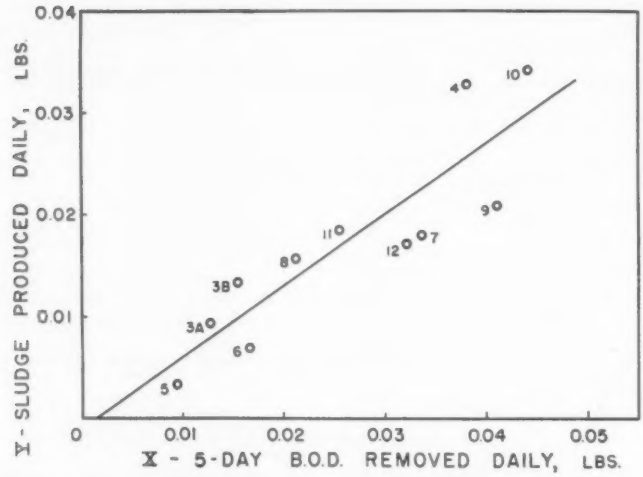

FIGURE 7.—Relation between B.O.D. removed and sludge produced. (Numbers represent runs from which observations were obtained.)

was unchanged, the degree of B.O.D. removal and the amount of sludge in the contact aerator attained constancy within 3 days.

Effect of Dissolved Oxygen Concentration

No effect upon the degree of B.O.D. removal was observed from variations in oxygen concentration, provided that a residual dissolved oxygen content existed in the mixed liquor at all times. The loading conditions of runs No. 7, 9, and 10, however, placed an overload on the contact aeration plant so that no measurable dissolved oxygen remained in the mixed liquor. An immediate decrease in the efficiency of B.O.D. removal was observed. In order that aerobic conditions could be maintained, it was necessary to supplement the air supply with gaseous

TABLE III.—Summary of Loading Parameters, All Runs

Run	Days	Loading[1] (lb. B.O.D. /day)	Sludge Weight[1] (lb.)	Detention[1] (hr.)	Sludge Weight Loading Parameter	Surface Area Loading Parameter	Efficiency of B.O.D. Removal[1] (%)
2	3,4,5	0.0394	0.0141	4.47	624	0.638	59.0
2	11,12,13,14	0.0382	0.0229	4.55	367	0.608	72.1
3A	2,3,4	0.0212	0.00967	4.39	499	0.350	60.1
3B	4,5,6,7	0.0241	0.0112	3.83	561	0.456	63.3
4	6,7,8	0.0795	0.0190	4.53	924	1.27	47.8
5	5,6,7,8	0.0124	0.00850	8.04	181	0.112	76.3
6	4,5,6	0.0224	0.0132	8.26	205	0.271	74.3
7	5,6,7,8	0.0428	0.0260	8.19	201	0.379	78.6
8	3,4,5,6	0.0476	0.0237	1.98	1010	1.74	44.5
9	3,4,5,6	0.0897	0.0387	1.98	1170	3.28	45.9
10	3,4,5,6	0.191	0.0618	2.05	1510	6.80	23.2
11	3,4,5,6	0.0448	0.0200	3.89	576	0.835	57.0
12	4,5,6,7,8,9	0.0447	0.0426	3.89	270	0.833	71.7

[1] Average.

oxygen. The resulting dissolved oxygen concentrations in the mixed liquor varied from 4 to 14 p.p.m., but no significant alteration in the efficiency of B.O.D. removal was observed.

Effect of Volatile Solids Content

Because the synthetic sewage was compounded from substances of high organic content, an activated sludge of relatively high volatile solids content developed. Determinations on the mixed liquor sludge indicated a volatile solids content of 70 to 94 per cent, with an average of about 85 per cent. During run No. 2, a quantity of inert water-pipe incrustations was inadvertently introduced into the storage tank. An increase in the sludge mass, accompanied by a reduced volatile solids percentage, resulted. Although the B.O.D. loading of the plant was not changed, the degree of B.O.D. removal was increased from 59 to 72 per cent, apparently as the result of the presence of an increased amount of sludge in the aeration tank.

Measurement of Sludge Produced

Suspended solids measurements of the plant effluent indicated that about one-half of the sludge squeegeed from the tank sides and sloughed from the contact plates upon removal was lost from the contact plant after each plate removal and squeegeeing operation. As the amount of sludge wasted from the contact aerator consisted of that removed on the 4 contact plates and that wasted in the plant effluent, it was possible to estimate the total sludge wasted during each plate changing operation. Likewise, suspended solids measurements on the influent and effluent sewage prior to each plate changing operation permitted an estimation of the solids continuously lost and gained by the contact aerator. From these data it was possible to compute the daily sludge production.

For the synthetic mixture employed, a relationship was found to exist between the amount of 5-day B.O.D. removed and the excess sludge produced. The data are shown in Figure 7. The line of best fit is given by

$$Y = -0.001 + 0.70X \qquad (2)$$

in which X is the pounds of 5-day B.O.D. removed daily, and Y is the pounds of sludge produced daily.

From this consideration, it is possible to predict the excess sludge produced from the synthetic mixture. The relation is

$$S = I + 0.7\,E\,x - F \qquad (3)$$

in which S is the pounds of excess sludge produced per day, I is the pounds of suspended solids in the inflowing sewage daily, E is the efficiency of B. O.D. removal expressed as a ratio, x is the pounds of 5-day B.O.D. applied per day, and F is the pounds of suspended solids in the effluent sewage per day. However, general use of Eq. 3 is limited because of the following reasons:

1. The factor 0.7 is not too firmly established. At the 95 per cent confidence level this factor may lie between 0.42 and 0.98.
2. Eq. 2 has not been tested over a wide range of sewages that differ in per cent volatile solids and in suspended solids concentration.
3. The detention periods used in obtaining the data are mostly shorter than in conventional activated sludge plants.

Surface Area Loading Parameter

The results of the contact aerator experiments were analyzed to determine the applicability of a surface area loading parameter similar to that developed by the N.R.C. (19). A loading parameter, expressed in pounds of 5-day B.O.D. applied daily per 1,000 sq. ft. of contact surface per hour of aeration, was computed for each run. Each parameter was computed from the data of a continuous period of op-

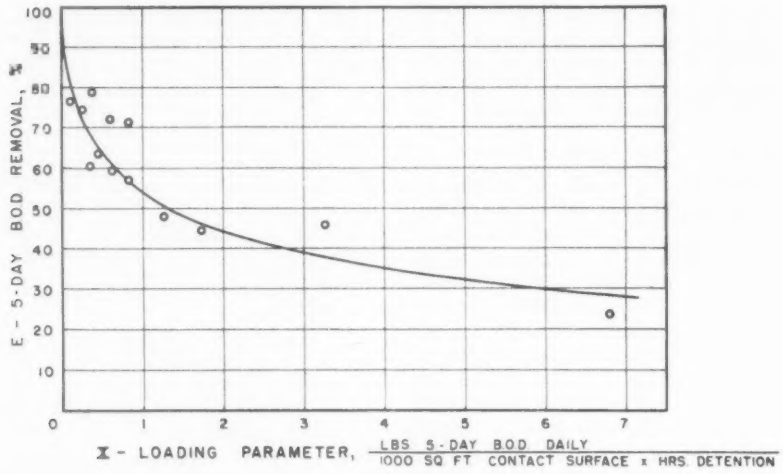

FIGURE 8.—Relation between surface area loading parameter and efficiency of B.O.D. removal.

eration of 3 to 6 days, during which equilibrium conditions obtained. Two periods of run No. 2 have been included because a marked change occurred in the percentage of volatile solids in the sludge on the sixth and ninth days of the run. The days selected and the weighted averages of B.O.D. loading, sludge weight, theoretical detention time, and efficiency of B.O.D. removal are summarized in Table III. The surface area of the contact aerator walls was assumed to be ineffective because of the daily squeegeeing operation.

A least-squares treatment of the data resulted in the relation

$$E = \frac{100}{1 + 0.79X^{0.565}} \qquad (4)$$

in which X is the loading parameter in the units given above, and E is the per cent efficiency of B.O.D. removal. The logarithmically transformed equation indicates fair correlation ($r = 0.87 \pm 0.03$) for the 13 points observed. The data are presented in Figure 8.

Eq. 4 is a poorer approximation of plant-scale operation than the relation obtained by the N.R.C. for at least two reasons: (a) plate rotation in the experimental unit tended to keep the sludge on the plates lower relative to that in the liquor, and (b) squeegeeing of the tank sides tended to keep a relatively higher sludge concentration in the liquor. Results closer to those of the N.R.C. probably would have been obtained had the contact plates of the experimental unit not been removed and cleaned.

Sludge Weight Loading Parameter

The 13 sets of data given in Table III were also computed on the basis of a sludge weight loading parameter. The loading parameter, X, was computed in terms of the pounds of 5-day B.O.D. applied daily per 1,000 lb. of suspended solids per hour of aeration.

A comparison with similar data from plant-scale activated sludge units has been used to test the applicability of these experimental data to plant-scale systems.

For this purpose, the results have been correlated with the data of Fair and Thomas (6) (Table IV). The 18

TABLE IV.—B.O.D. Loading and Efficiency of 18 North American Activated Sludge Plants[1]

Plant	Period of Operation	Average Flow (m.g.d.)	B.O.D. Loading $\left(\frac{x}{WT}\right)$	Efficiency of Aeration and Secondary Settling (%)
Ann Arbor, Mich.	1944–46	5.0	41.7	87.8
Austin, Tex.	1944	4.7	34.1	88.6
Baltimore, Md.	1945	108.2	36.6	91.9
Chicago, Ill.:				
Calumet	1946	73.7	19.8	87.7
North Side	1946	200.3	20.0	87.9
Fort Wayne, Ind.	1941–45	17.5	19.0	89.4
Hammond, Ind.	1942–46	21.0	14.3	90.8
Indianapolis, Ind.	1930–40	—	16.6	88.0
East Milwaukee, Wis.	1936–40	44.1	3.74	93.5
West Milwaukee, Wis.	1930–40	77.4	13.4	92.9
Omaha, Neb.	1946	2.5	19.6	88.0
Peoria, Ill.	1931–40	11.6	19.7	89.0
Richmond, Ind.	1942–46	5.5	20.5	93.8
Rockville Centre, N. Y.	1935–40	1.96	155	79.8
Springfield, Ill.	1930–40	6.9	23.8	88.3
Syracuse, N. Y.	1947	4.3	49.3	87.0
North Toronto, Ont.	1935–40	7.1	22.0	90.8
New York, N. Y.[2]	1938–40	174.0	38.8	88.9

[1] From reference (6).
[2] Wards Island.

activated sludge plants selected are not known to treat excessive amounts of industrial wastes. The results obtained from these 18 plants and the 13 observations of the author are presented in Figure 9. The line of best fit conforms to the two-parameter equation

$$E = \frac{100}{1 + 0.0194X^{0.571}} \qquad (5)$$

The degree of correlation for the normalized form of this equation is high ($r = 0.952 \pm 0.004$), and the overlap of the two sets of data suggests that the biological characteristics of the B.O.D. removal process are probably the same in both sets of operations. As a matter of empirical curve fitting, however, it was found that

$$E = \frac{100}{1 + 0.00266(X + 45)^{0.880}} \qquad (6)$$

fits the data with a somewhat higher degree of correlation ($r = 0.975 \pm 0.002$). Eq. 6 represents the curve shown in Figure 9.

Sample Computations Using the Loading Parameter

As a result of these comparisons, it is felt that the relationship shown by Eq. 6 is useful over high and intermediate ranges of activated sludge treatment. This equation should be of use in the design of new activated sludge plants and in the operation of existing plants. Its use is perhaps best illustrated by means of sample problems, two of which are given as follows:

Example No. 1—An activated sludge plant is to be designed for a municipality which will produce 4 m.g.d. of domestic sewage. Tests on the raw sewage indicate that after settling for 2 hr. the sewage contained an average 5-day, 20° C. B.O.D. of 150 p.p.m. Removal of 90 per cent of the B.O.D. from the settled sewage is necessary to prevent nuisance conditions in the receiving stream. Cooperative pilot plant experiments by an air diffuser manufacturing firm and the designing engineer indicate that the diffuser tested will maintain an average D.O.

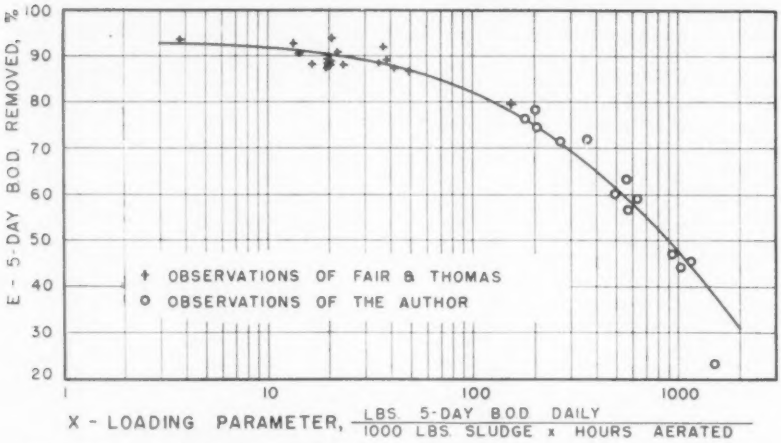

FIGURE 9.—Relation between sludge weight loading parameter and efficiency of B.O.D. removal.

concentration of 2 p.p.m. at an activated sludge concentration of 2,000 p.p.m. under normal feeding conditions, provided the diffusers are placed 10 ft. below the liquid surface. What aeration tank dimensions are necessary to produce the desired results?

B.O.D. loading = $4 \times 8.34 \times 150$ = 5,000 lb. per day. From Eq. 6,

$$90 = \frac{100}{1 + 0.00266(X + 45)^{0.880}}$$

Solving this equation for the loading parameter, it is found that $X = 24.5$.

As the B.O.D. loading, x, is known, the loading parameter may be simplified to $\frac{5{,}000}{W\,T} = 24.5$, or $W\,T = 204 = \frac{2{,}000}{1{,}000} \times 8.34\,V\,T$, in which V = volume of tank, in million gallons. But $V = 4T/24$, so $204 = 2 \times 8.34 \times \frac{4}{24}T^2$, from which $T = 8.56$ hr. and $V = \frac{4 \times 8.56}{24}$ = 1.427 m.g. = 191,000 cu. ft. If the tank depth is 10 ft., a surface area of 19,100 sq. ft. is required. For a 1 to 4 ratio of width to length, the theoretical length would have to be 276.4 ft. and the width 69.1 ft.

Example No. 2—An existing activated sludge plant has a theoretical detention period in the aeration chamber of 6 hr. The average daily load applied to the aerator is 1,000 lb. of 5-day, 20° C. B.O.D. in a flow of 1.5 m.g.d. What sludge concentration must be maintained in the aerator to assure 86 per cent B.O.D. removal by the aerator and secondary settling basin?

From Eq. 6,

$$86 = \frac{100}{1 + 0.00266(X + 45)^{0.880}}$$

Solving this equation for the loading parameter, and substituting known values of daily B.O.D. load and time of contact, it is found that $X = \frac{1{,}000}{6\,W} = 62$, or $W = 2.69$ thousand lb. of sludge. Also, the aerator tank volume $= \frac{1{,}500{,}000}{4} = 375{,}000$ gal. Therefore, the sludge concentration $= \frac{2{,}690}{0.375 \times 8.34} = 861$ p.p.m.

Summary and Conclusions

1. Within the range of normal operation the dissolved oxygen concentra-

tion in the mixed liquor of submerged, aerobic, biological sewage treatment systems does not affect the efficiency of B.O.D. removals. If the system becomes anaerobic, an immediate decrease in efficiency results.

2. The efficiency of B.O.D. removal of an activated sludge system is a function of the total sludge mass present. Within the range of about 70 to 94 per cent volatile solids, no variation in the ability of an activated sludge to remove B.O.D. from the substrate was observed.

3. The amount of excess sludge produced by submerged, aerobic, biological sewage treatment methods is determined by the net weight of suspended solids introduced by the inflowing sewage and by the amount of B.O.D. removed from the substrate. For the organic substrate employed, the relation is expressed by Eq. 3. At the 95 per cent confidence level the factor 0.7 lies between 0.42 and 0.98, so this excess sludge relation should be used with caution.

4. A relationship has been shown to exist between the contact surface area of a contact aeration plant and the efficiency of B.O.D. removal. The relation expressing the results of these studies is given by Eq. 4, the normalized form of which indicates fair correlation ($r = 0.87 \pm 0.03$) for the experimental data.

5. The degree of B.O.D. removal is closely related to the time of contact, the applied B.O.D. load, and the total weight of sludge in the aeration tank. These variables have been combined into a sludge weight loading parameter, X, expressed as pounds of 5-day B.O.D. applied daily per 1,000 lb. of sludge per hour of aeration.

Thirteen observations of the author have been correlated with the data of 18 activated sludge plants. The resulting relation between the loading parameter and the efficiency of B.O.D. removal is expressed by Eq. 6, which shows a high degree of correlation ($r = 0.975 \pm 0.002$). The equation permits design for and operational control of the efficiency of B.O.D. removal by activated sludge treatment plants.

Acknowledgments

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MEASUREMENT OF CARBON DIOXIDE EVOLUTION FROM AERATED SLUDGE

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The rate and extent of the oxidizing ability or activity of an aerated sludge may be measured in the simple manner described herein. The direct measurement of oxygen uptake of a sludge requires manometric methods with apparatus and technique not generally available for routine practice. On the other hand, the described measurement of the amount of CO_2 evolved from a sludge-substrate mixture is easy, direct, and relatively rapid. It offers a tool for ascertaining the potency of the sludge and should find application.

The possibility of utilizing CO_2 production as a measurement of sludge activity devolved from a prior study on the assimilation of dairy waste (3). That investigation was made by means of the Warburg apparatus. Solutions of skim milk (1,000 p.p.m.), lactose (500 p.p.m.), and casein (350 p.p.m.) each had its own rate and extent of oxidation when acted upon by the sludge organisms. The activity was essentially complete in 6 hr. Analyses showed that 60 to 68 per cent of the substrate was converted to cell material, whereas the remainder was oxidized.

Determinations of the respiratory quotient (R.Q.) for each of these systems demonstrated that the volume of CO_2 evolved was practically equal to the oxygen consumed; that is, R.Q. = $CO_2/O_2 = 1$. Thus, it appeared obvious that under a highly aerobic environment, the CO_2 evolved may serve as a measure of sludge activity.

Apparatus

A simple device for the measurement of CO_2 evolution from sludge is pictured in Figure 1. The principles of the apparatus are not novel. A similar apparatus finds use in studying the microorganisms in soil (1). In the latter case, days or weeks are required, whereas with aerated sludge the test is completed in a short while. Briefly, CO_2-free air is passed through the sludge-substrate mixture and the spent CO_2-laden air is bubbled through barium hydroxide solution. The air is forced through under pressure or vacuum. In the studies here reported compressed air was available at 20 lb. gage pressure.

A list of the materials used in this apparatus follows:

1 Drying tower or calcium chloride cylinder.
1 Flowmeter.
1 Quart Mason jar with removable ring of a two-piece Mason cap.
1 Rubber stopper No. 13 with 3 holes.
1 Tube, gas dispersion; with fritted disc, Pyrex No. 39525/20M.
1 Calcium chloride drying tube, 100 mm.
1 Funnel, separatory, cylindrical, 125 ml.
2 Culture tubes, 25 by 300 mm.
1 Culture tube, 25 by 200 mm.
2 Tubes, gas dispersion, with fritted cylinders, Pyrex No. 39533/12C.
1 Tube, glass with Rose bulb at one end.

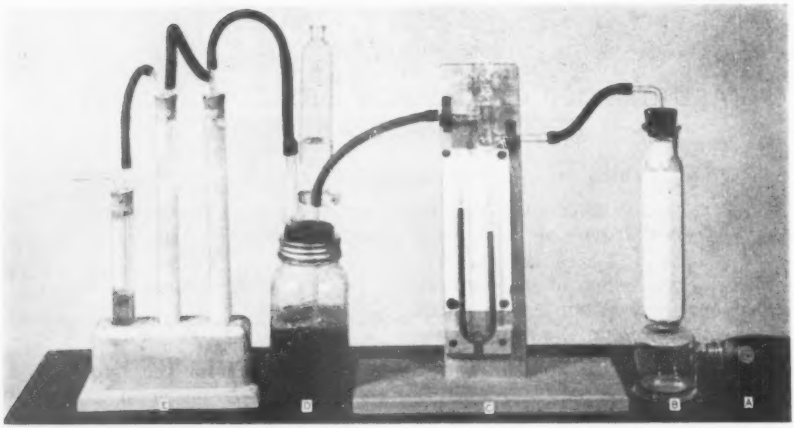

FIGURE 1.—Apparatus for measuring carbon dioxide evolution from aerated sludge substrate mixtures. A, air regulating valve; B, soda-lime tower; C, flowmeter; D, quart jar aerator; E, tubes containing $Ba(OH)_2$.

Rubber stoppers and tubing as required.
Silicone, D–C antifoam A.
Soda-lime, 4 to 8 mesh.

In addition, the following reagents are required:

$Ba(OH)_2$, 0.1N, containing 8.57 g. anhydrous or 15.78 g. hydrous per liter.
Oxalic acid, 0.1N, containing 6.3 g. of the hydrate per liter.

Details are shown in Figure 1. The flow of compressed air is regulated by the needle valve (A). The air passes up through the tower (B) containing soda-lime for CO_2 removal. The CO_2-free air is measured by means of the flowmeter (C) and regulated by valve (A) to give a rate of flow of one volume per volume of sludge mixture per minute (500 ml. air per 500 ml. mixture per minute). The air is dispersed in the 500 ml. of sludge-substrate mixture contained in the quart jar (D). The gas dispersion tube with fritted disc serves as the sparger. The spent air, carrying evolved CO_2, leaves the jar through the upright tube containing glass wool and enters the three tubes (E) containing 25 ml. 0.1N $Ba(OH)_2$, water, and phenolphthalein. (The glass wool prevents passage of liquid droplets.) Thorough removal of the CO_2 by the $Ba(OH)_2$ is secured by using the two gas dispersion tubes with fritted cylinders in the first two test tubes, as shown. The third contains the tube with the Rose bulb; that is, the end of the tube is blown to form a small bulb and is perforated with three or four holes.

Figure 1 shows a single outfit. In most of the experiments at least five were used at one time. In that case, the air scrubbing tower was replaced by a 40-in. length of 2-in. pipe attached to the compressed air line. This held about 2 lb. of soda lime. The CO_2-free air was distributed through flowmeters by means of a manifold equipped with needle valves. The air also may be prepared by bubbling through caustic solution.

Procedure

Place 140 ml. of settled sludge in the jar. Insert the three-hole stopper with the assembly in the mouth of the jar and fasten in place with the Mason

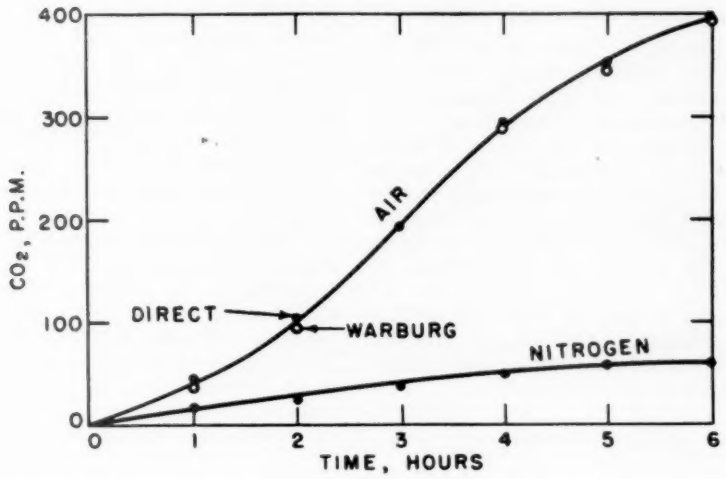

FIGURE 2.—Carbon dioxide production from skim milk in air and in nitrogen.

cap ring. Connect the sparger tube with the flowmeter. Pass CO_2-free air through the apparatus for 15 min. to sweep out residual CO_2. Stop the air flow. Add 360 ml. sewage or substrate through the separatory funnel to give a final volume of 500 ml. Close the glass cock. Connect the upright spent air tube with the three tubes containing the $Ba(OH)_2$ solution. Pass air through the apparatus and regulate the rate of flow. Add silicone antifoam to aerating mixture and to the $Ba(OH)_2$ tubes. Aerate for 1 hr. and replace the $Ba(OH)_2$-containing tubes with another set of tubes containing 25 ml. of $Ba(OH)_2$ solution. Permit air to flow during the interchange in order to avoid back passage of the solution. Transfer the contents of the three tubes to a 500-ml. flask and titrate with the oxalic acid to the colorless phenolphthalein end point. Replace the tubes containing $Ba(OH)_2$ at hourly or other desired intervals. Calculate the results and plot the data. The ratio of sludge to sewage may be varied to simulate operating conditions.

Calculations

The spent air from the aerator is relieved of the CO_2, thus

$$CO_2 + Ba(OH)_2 \rightarrow BaCO_3 + H_2O.$$

Hence, 1 ml. 0.1N $Ba(OH)_2$ = 1 ml. 0.1N CO_2 = 2.2 mg. CO_2. The $BaCO_3$ precipitates as an insoluble salt. The excess $Ba(OH)_2$ is titrated by the oxalic acid, which does not react with the $BaCO_3$. The difference in value between the $Ba(OH)_2$ present at the beginning in the 25 ml. of standard solution and that found by the oxalic acid gives the amount of $Ba(OH)_2$ combined with CO_2

An example follows:

25 ml. $Ba(OH)_2$, 0.1181N, at start	= 29.52 ml. 0.1N
15.4 ml. oxalic acid, 0.1343N, back titration	= 20.68 ml. 0.1N
$Ba(OH)_2$ carbonated, by difference	= 8.84 ml. 0.1N
CO_2 produced per aerator of 500 ml.	= 19.45 mg.
CO_2 produced, mg. per liter or	38.9 p.p.m.

Experimental Applications

Comparisons between the CO_2 obtained from the aerators with that calculated from the direct oxygen uptake measured manometrically have been made using dairy waste sludge and various substrates (5). Results showed excellent correlation between these two methods. Some of the values were plotted in Figure 2. Replacing air by nitrogen gas inhibited the activity of the sludge, retarded the oxidation of the skim milk, and resulted in reduced formation of CO_2. The CO_2 obtained with a water blank was practically negligible (4 p.p.m.)

was used in the Warburg vessel. The results presented in Figure 2 have taken the dilutions into consideration.

A peculiarity occurred when a 0.35 per cent casein solution was used instead of the skim milk solution. The CO_2 calculated from the O_2 consumed in the Warburg vessel was consistently about twice as great as that evolved from the jar aerators. Apparently, the alkaline substances produced by the oxidation of the proteins combined with some of the CO_2, preventing its removal from the aerating sludge. Acidifying the contents of the jar to pH 3 or lower with H_2SO_4 after the

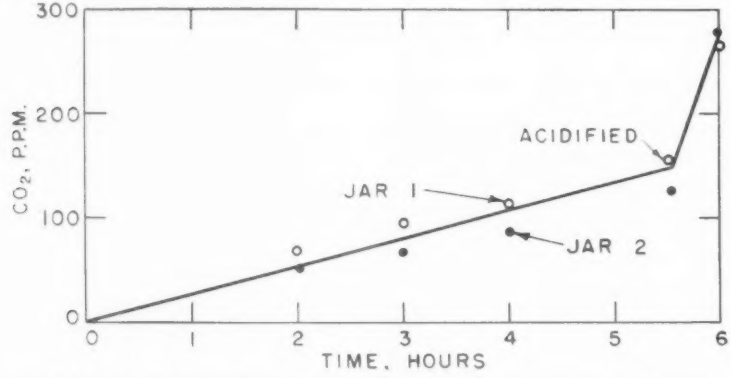

FIGURE 3.—Carbon dioxide evolved from casein showing importance of acidification after aeration period.

Some tests were made using 500 ml. of aerated diluted dairy waste sludge in the quart jar (D) and 3 ml. in the Warburg vessel. The total chemical oxygen consumed was 416 p.p.m., of which 42 p.p.m. was present in the supernatant solution after centrifuging. By difference, the chemical oxygen consumed by the solids was 374 p.p.m., which was calculated as 298 p.p.m. of bacterial cells using the factor of 1.25 g. O_2 required to oxidize per gram of dry cells (3). Fifty ml. of 1 per cent skim milk solution were added without additional dilution to the aerator (D) through the separatory funnel; 0.3 ml.

aeration period and then continuing aeration for 30 min. gave the results shown in Figure 3. The CO_2 output was practically doubled. When using a highly proteinaceous material or one that may produce an alkaline condition, acidification will be necessary at the end of the aeration period to obtain a true value for the CO_2 production. Use of buffers may be desirable in some cases.

Some experiments were made with municipal sludge and sewage obtained locally, through the courtesy of R. M. Bolenius of the Abington Township (Pa.) sewage treatment plant. The

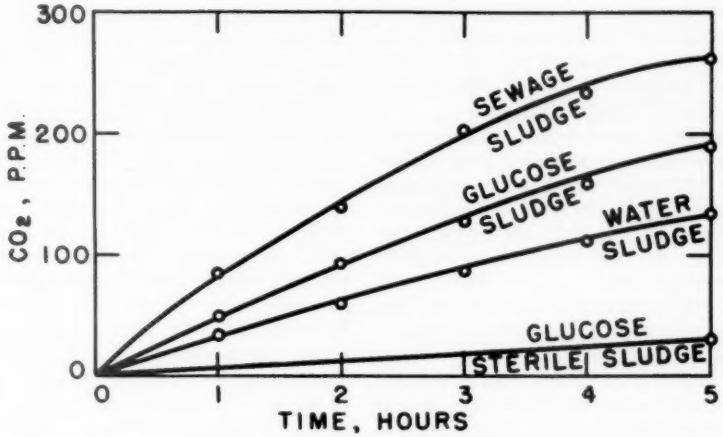

FIGURE 4.—Evolution of carbon dioxide from 40 parts municipal sludge plus 100 parts substrate.

CO_2 evolved from 40 parts of fresh settled sludge and 100 parts sewage was compared to that in which the sewage was replaced by glucose and by water. To 140 ml. of fresh sludge placed in the jar, 360 ml. of sewage, glucose solution, or water were added. The sludge-sewage mixture was very active in the liberation of CO_2. The sewage had a chemical oxygen consumed value of 288 p.p.m. The 200-p.p.m. glucose-sludge mixture was less active. A later test showed that CO_2 production was increased slightly by the addition of $(NH_4)_2SO_4$. When water replaced the sewage, activity was still marked, but reduced about one-half; apparently the sludge has large amounts of available nutrients. Heat-sterilized sludge, to which the glucose

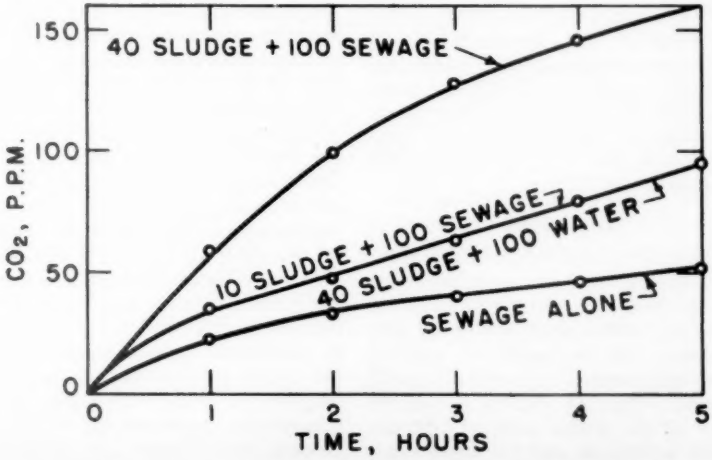

FIGURE 5.—Carbon dioxide formed by 500 ml. of sewage-sludge mixtures.

solution was added, showed only slight activity. In this experiment, the water blank had a value of 53 p.p.m. The data, corrected for the water blank, have been plotted in Figure 4.

An experiment in which heat-sterilized sewage was added to fresh sludge and to heated sludge gave values of 63 p.p.m. CO_2 liberated from the latter in 5 hr. and 282 p.p.m. from the former. A viable sludge was necessary to produce CO_2.

Using freshly obtained materials, the ratio of sludge to sewage was altered in order to note the effect of decreasing the quantity of sludge. To 100 parts of sewage were added 40, 10, and 0 parts of sludge. To another 40 parts of sludge were added 100 parts of water. The total volume added to each aerator was 500 ml. The differences in activity were readily obvious from the plotted CO_2 data (Figure 5). In this test the soda lime in the absorption chamber had been changed and a low value of 10 p.p.m. CO_2 was obtained with the water blank.

The manometric Warburg experiments were conducted at 30° C. with the close control of temperature required for such measurements. The titrimetric experiments described were carried out at room temperature, which was about 27° C. in the laboratory. If the laboratory temperature varies appreciably (more than 2° C.) the quart jar should be placed in a water or air thermostat so that the activity of various sludges would be measured under comparable conditions.

Discussion

The oxidation occurring in a mixture of aerating sludge and waste is caused by the activity of microorganisms. These organisms produce CO_2 in proportion to the amount of O_2 used in obtaining energy for synthesizing cell material. The CO_2 evolved is a direct index of the sludge activity. If the sludge is sluggish and the waste is attacked slowly, CO_2 production is retarded. If the sludge activity is destroyed, there is little or no CO_2 formation. Such destruction may occur with toxic wastes. An active sludge with nutrients balanced, as in dairy waste or household sewage, is associated with rapid and high CO_2 evolution. The greater the amount of sludge used with the sewage, the faster the latter is utilized and the more rapid is CO_2 formation. Conversely, smaller amounts of sludge produced CO_2 more slowly. Likewise, an insufficiency of oxygen results in decreased amounts of CO_2.

The measurement of CO_2 in the simple manner described offers a tool of value in many phases of waste disposal. Within a short time (as short as 1 hr. in some cases) considerable information may be obtained about the sludge and about the sewage. The oxidizing ability of the sludge may be measured and an indication obtained as to the amount required for mixing with the influent. The amount of sewage to be added to sludge and the necessity of supplemental nutrients may be determined. The amount of sludge solids produced from a waste in the aeration process may be calculated also. In addition, information may be obtained concerning the oxygen requirements of the sludge-waste mixtures. Since the quantity of oxygen equals the quantity of CO_2 under these conditions, the volume of O_2 required per milligram of cells per hour is equal to the volume of CO_2 evolved per milligram of cells per hour.

The results of the few experiments upon sewage indicate that the recommended procedure could be adapted for the determination of B.O.D. Thus in 5 hr. (Figure 5) the sewage alone has produced 50 p.p.m. CO_2, which is equivalent to $0.727 \times 50 = 36$ p.p.m. O_2 consumed. Oxygen consumption by the rapid growth reaction would be complete in 3 days according to the manometric measurements of Ludwig, Oswald, and Gotaas (4). Results of like nature were obtained by Gellman

and Heukelekian (2) with a Sierp apparatus. The slower endogenous respiration of the organisms would require many days to reach a negligibly slow rate, just as is required for the conventional B.O.D. determination. Further investigation of this application would seem to be a promising line of research.

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OHIO SEWAGE TREATMENT WORKS GUIDE

Under the title "How to Get Sewage Treatment Works in Ohio," the Ohio Department of Health and the Ohio River Valley Water Sanitation Commission recently issued a guide describing recommended step-by-step engineering and financial procedures for councilmen, mayors and city managers, service directors, solicitors and fiscal officers, engineers, and public spirited citizens interested in clean waters. The 40-page guide, although written specifically for Ohio conditions, because of the local variations in charters and other conditions of operation is necessarily so general in scope as to be useable as a reference even in other states.

Among the subjects discussed are the necessity for sewage treatment, who will have to build treatment works, the consulting engineer's role, planning of financing, types of bonds and their application, sewer service charges, acquisition of the treatment plant site, awarding of the construction contract, and personnel requirements in management and operation of the finished project. Appendices discuss county sewer districts and conservancy districts, give references to the provisions of the constitution and laws of Ohio on financing sewage works improvements, and summarize some important legal decisions affecting sewage works financing.

Copies of the guide are obtainable at $1.00 each from the Ohio State Department of Health, State Office Building, Columbus 15, Ohio, or the Ohio River Valley Water Sanitation Commission, 414 Walnut St., Cincinnati 2, Ohio.

COLORIMETRIC DETERMINATION OF FREE AMMONIA WITH A PYRIDINE–PYRAZOLONE REAGENT

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The determination of free ammonia is one of the most frequent and important analytical procedures in water analysis. Generally, there is little trouble in determining macro amounts of ammonia, but the determination of less than 10 p.p.m. has been restricted almost entirely to the use of Nessler's reagent. Although this reagent can be used to determine very small amounts of ammonia, it has several disadvantages, such as formation of turbidity or precipitates, shifts in calibration curve from day to day, the requirement of Nessler tubes, and interference by some cations, notably Mg^{++}.

In this paper, a new method for the determination of ammonia is proposed. The main advantages of this method are an increase in sensitivity, so that 1-cm. cells and any photometer can be used to measure as little as 0.025 p.p.m. of ammonia nitrogen, and the fact that the color formed is stable and reproducible, so that a single calibration curve is sufficient. Other advantages are high precision, a relative freedom from interferences, and the fact that extraction with carbon tetrachloride makes the method independent of any coloration of the original sample. The only interfering cations are silver, copper, zinc, and more than 50 p.p.m. iron. Calcium and magnesium do not interfere. The cyanide group anions, namely cyanide, thiocyanate, and cyanate, also will form colors with the reagent and therefore have to be removed. If cyanate is present, it is hydrolyzed to ammonia and determined as the latter. The authors have used this fact to develop a method for the determination of cyanate.

A statistical study of the method, in which known ammonia concentrations in sewage were determined, showed a standard deviation of about 3.5 per cent for ammonia concentrations of 0.025 to 2.5 p.p.m.

In the procedure, the sample is treated with chloramine-T and then a pyridine-pyrazolone reagent to form a purple color. The solution is extracted with carbon tetrachloride to increase the sensitivity, stabilize the color, and circumvent the effect of colored samples. The color in the carbon tetrachloride extract is stable for several hours.

Inasmuch as the solution is extracted and no turbidity is encountered, distillation will usually not be required. If for any reason distillation of the ammonia is desired, the method described in "Standard Methods" (1) should be used.

1. Apparatus

1.1. Spectrophotometer, or photoelectric filter photometer transmitting at 450 mμ.

1.2. Separatory funnels, 125-ml.

1.3. Transfer pipet, 1-ml., graduated.

1.4. Volumetric flasks, 50- and 25-ml.

2. Reagents

2.1. Buffer, pH 3.7. To 45 ml. of 10 per cent sodium acetate in 440 ml. of water add enough concentrated acetic acid to give a pH of 3.7.

2.2. Carbon tetrachloride, cp. The carbon tetrachloride used in the pro-

cedure may be repurified by distillation.

2.3. Chloramine-T, 3 per cent. Dissolve 0.6 g. of chloramine-T in 20 ml. of water.

2.4. 3-methyl-1-phenyl-5-pyrazolone. The pyrazolone is recrystallized twice from 95 per cent ethanol, and can then be stored for months in a dark bottle.

2.5. Bis-(3-methyl-1-phenyl-5-pyrazolone). Dissolve 17.4 g. of the recrystallized 3-methyl-1-phenyl-5-pyrazolone in 100 ml. of 95 per cent ethanol, add 25 g. of phenylhydrazine, and reflux. Filter off the insoluble product, which is the bis-pyrazolone, at intervals of a few hours, returning the hot filtrate for further refluxing. The reaction may be continued for several days and a yield of more than 60 per cent obtained. Wash the bis-pyrazolone with several portions of hot 95 per cent ethanol. It may then be stored for months.

2.6. Pyridine-pyrazolone reagent. Dissolve 0.63 g. of recrystallized 3-methyl-1-phenyl-5-pyrazolone in 250 ml. of water by heating the water to about 75° C. and stirring while it cools to room temperature. To this solution add 50 ml. of redistilled pyridine containing 0.05 g. of the bis-pyrazolone. The bis-pyrazolone will dissolve in the pyridine on standing for about 45 min. The pyridine solution should be freshly prepared and the solution should be mixed only shortly before use. The aqueous pyridine solution may be stored for two or three days.

2.7. Standard ammonia solution. For the stock solution dissolve 0.1474 g. of ammonium sulfate in ammonia-free distilled water and dilute to 250 ml. The standard solution is prepared from this solution by diluting 20 ml. of the stock solution to 1 l. with ammonia-free water. One ml. contains 0.0025 mg. of nitrogen.

2.8. Water, ammonia-free. Ammonia-free water may be prepared (a) by redistillation of distilled water that has been treated with bromine and allowed to stand overnight; or (b) by passing distilled water through a cation exchange column containing Nalcite HCR or any similar sulfonic acid or styrene cation exchange resin.

3. Procedure

3.0. Preparation of the standard curve. Dilute 1-, 2-, 5-, 10-, 25-, and 50-ml. aliquots of the standard solution to 50-ml. in 125-ml. separatory funnels, and treat as described in 3.2. Plot milligrams of ammonia nitrogen *vs.* absorbency.

3.1. Analysis of the sample. Filter the sample to remove solids, or let the solids settle out and use the supernatant liquid. Transfer a 50-ml. aliquot to a beaker, adjust the pH to about 3.7, and transfer the solution to a 125-ml. separatory funnel. Rinse the beaker with a few ml. of water, and add these washings to the sample in the separatory funnel.

3.2. Add 10 ml. of the buffer solution (2.1). Add 0.9 ml. of 3 per cent chloramine-T, stopper, and shake. Add 30 ml. of the pyridine-pyrazolone reagent 90 sec. after the addition of the chloramine-T and shake the funnel. After about 120 sec. extract the solution with 25 or 50 ml. of carbon tetrachloride. Filter the carbon tetrachloride through cotton plugs (to remove water droplets) into volumetric flasks. If the color of the aqueous phase before extraction is only a pale purple, 25 ml. of carbon tetrachloride should be used; otherwise, use 50 ml.

3.3. Measure the absorbency of the sample at 450 mμ. and obtain the amount of ammonia nitrogen present from the standard curve. A reagent blank containing only 50 ml. of ammonia-free distilled water must be tested with each set of determinations, and the absorbency of the blank subtracted from the measured absorbencies.

$$\text{p.p.m. N} = \frac{\text{mg. N}}{2.5} \times \text{ml. } CCl_4 \text{ used}$$

3.4. Note: If cyanate or more than 0.25 p.p.m. of cyanide or thiocyanate are present originally, the sample solution should be passed through an anion exchange resin prior to being buffered. If all three of these anions are absent, the time between the addition of the pyridine-pyrazolone reagent and the extraction with carbon tetrachloride may be reduced to 60 sec.

Acknowledgment

The authors wish to express their appreciation to the U. S. Public Health Service for financial support of this project through a research grant from the National Institutes of Health, and to the Federation of Sewage and Industrial Wastes Associations, under whose auspices the research was conducted. Special thanks are due W. D. Hatfield, the coordinator for the project.

Reference

1. "Standard Methods for the Examination of Water and Sewage." 9th Edition. Amer. Pub. Health Assn., New York, N. Y. (1946).

MAKE YOUR HOTEL RESERVATIONS FOR THE FSIWA SILVER ANNIVERSARY MEETING

The Hotel Statler at New York City will be the headquarters for the Federation's Twenty-Fifth Annual Meeting, to be held in October. An outstanding Silver Anniversary program is being planned for the four-day meeting.

Requests for room reservations should be addressed directly to the hotel. It should be noted that the technical program will open on Monday morning, October 6, and will close at noon on Thursday, October 9. However, the usual inspection trip will this year be scheduled for the afternoon of October 9, after the close of the meeting.

WRITE NOW FOR YOUR RESERVATIONS!

Industrial Wastes

METAL RECOVERY BY ION EXCHANGE*

By T. J. Fadgen

Chief Chemist, Ternstedt Division, General Motors Corporation, Trenton, N. J.

The attitude toward, and the conception of what is referred to as "stream pollution," has changed rapidly during the past few years. It has become completely associated and interwoven with the necessity for conserving the use of water to minimize the drain upon municipal supplies.

The first step taken toward attacking the water consumption problem must be in the nature of a survey of all water-consuming equipment or processes within a plant. Such surveys have been made at the Ternstedt Division of the General Motors Corporation.

As a result, automatic shut-off valves have been installed on many items of equipment that had been manually operated. Meters have been installed on the automatic plating conveyors and the daily consumption figures are given to plant supervisors who are charged with the responsibility for keeping water consumption within the "norm" that has been established for the process. A considerable volume of water is made to perform several tasks before being discharged from the plant; a lake has been constructed to collect uncontaminated cooling waters for return to the plant for further use.

The bulk of wastes discharged from plants performing electroplating operations are in the nature of large volumes of water containing small amounts of plating chemicals. These are usually referred to as rinse waters and would be difficult to treat by conventional methods.

In line with company interest in both pollution abatement and water conservation, it was believed that consideration should be given to possible treatment of these rinse waters. A method was desired which would extract the small quantities of plating chemicals from the waters, concentrate them into a small volume and, at the same time, make it possible to return the uncontaminated water to the plant for further use. This was the water conservation aspect. In the event that the chemicals could not be recovered in a usable form, their more concentrated but reduced volume would make it possible to treat them by well-recognized methods. This, of course, would be an extension of existing trade waste treatment operations, and a further contribution to pollution abatement.

Reference to the recovery of the plating chemicals in a usable form does not indicate that treatment procedures can be conducted on a profitable basis. Such a fortunate result can be attained in only rare instances. However, every effort should be directed toward securing every economic advantage possible without a sacrifice of the basic objective.

As a preliminary estimate, it appeared that ion exchange offered the best possible approach. Therefore, efforts were concentrated in this field. Some information is available in the literature concerning the use of ion exchange resins, but little of it is of

* Presented at 26th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

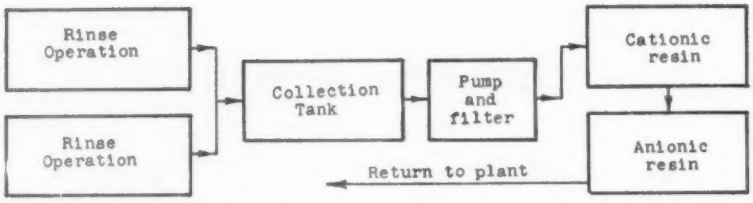

FIGURE 1.—Process cycle for plating rinse water treatment by ion exchange.

a nature that can readily be translated into answers to the three questions which every business must have—namely, (a) size of equipment, (b) operating costs, and (c) potential accomplishment. The data given in this report are based on laboratory studies made for the purpose of securing answers to these questions.

What is Ion Exchange?

Visually, the ion exchange process is seen as the passage of a liquid through beds of granulated plastic. This plastic can be of varying chemical structure, but each plastic pebble has attached to it a mobile ion. Chemically, it is the trading of these mobile ions for ions in solution in the rinse water.

The thing that makes the ion exchange reaction different from the ordinary chemical type is that the resins are insoluble and only the mobile ion takes part in the exchange reaction.

The chemical mechanics can best be illustrated by the reaction that takes place when rinse water from a chrome plating operation is treated, as follows (see Figure 1).

Separation

$$\underset{\text{No. 410 resin, hydroxyl cycle}}{2\,(RNH_3)OH} + \underset{\text{Chromic acid rinse water}}{2\,H_2CrO_4} \rightarrow \underset{\text{Exhausted No. 410 resin}}{(RNH_3)_2CrO_4} + \underset{\text{Water}}{H_2O}$$

Regeneration

$$\underset{\text{Exhausted No. 410 resin}}{(RNH_3)CrO_4} + \underset{\text{Sodium hydroxide}}{2\,NaOH} \rightarrow \underset{\text{No. 410 resin, hydroxyl cycle}}{2\,R(NH_3)OH} + \underset{\text{Sodium chromate}}{2\,Na_2CrO_4}$$

The process regeneration cycle is shown in Figure 2.

Recovery Methods

Method I—Recovery as barium chromate.

$$\underset{\text{Sodium chromate}}{Na_2CrO_4} + \underset{\text{Barium hydroxide}}{Ba(OH)_2} \rightarrow \underset{\text{Sodium hydroxide}}{2\,NaOH} + \underset{\text{Barium chromate}}{BaCrO_4\downarrow}$$

Method II—Recovery as chromic acid.

$$\underset{\text{Sodium chromate}}{Na_2CrO_4} + \underset{\text{IR 120 Resin, hydrogen cycle}}{2\,(RSO_3)H} \rightarrow \underset{\text{IR 120 Resin, exhausted}}{2\,(RSO_3)Na} + \underset{\text{Chromic acid}}{H_2CrO_4}$$

Resin Capacity

The theoretical capacity of a resin differs from the practical, not so much because the theoretical cannot be closely approximated, but because the economics do not always warrant the achieving of that goal. If reactivating and flushing after initial exhaustion is carried to a degree whereby the resins are restored to their full theoretical and original capacity, then there will be accomplished so little reduction in the volume of the discharge to the sewers that the whole process is hardly justified.

After the first few runs through a bed, there is a levelling off of the degree of reactivation which can be accomplished by a single reactivation and flush treatment. This can be illustrated on the basis of actual performance data.

Assume a resin bed size that theoretically will treat 100 gal. of a solution at some established concentration. The initial run to exhaustion will treat 100 gal. before it is necessary to reactivate and flush. The second run to exhaustion will treat 86 gal., with succeeding runs taking 57.7, 54, and 57.7 gal., respectively. All subsequent runs to exhaustion fall within the 54- to 57.7-gal. range. This occurs when the concentration of the regenerating solution follows that specified. Decreasing the hydroxide or acid concentrations below those specified will not properly restore the resins. On the other hand, a tripling of the concentrations of these two chemicals will not raise the resin exchange capacity beyond that for the second run shown above. Bed sizes given in this report are calculated on a 55 per cent efficiency basis, and allowance was made for this factor in establishing operating characteristics. This standard was used because the objective of any plant operation is uniformity of repetitive operations and not necessarily the duplication of basic data. Any operation which repeats consistently within any established standard can be considered as operating satisfactorily.

One of the factors which must be considered when establishing resin performance data is the presence of organic addition agents in the rinse waters from a plating operation. Their action is in the nature of a blocking off of a portion of the effective absorbing surface of the resin and their effect upon the resin is in proportion to their molecular size. This effect was not studied with respect to nickel plating rinses, but is recorded later with respect to copper.

This blocking off of the surfaces of the resins can probably be reduced, if

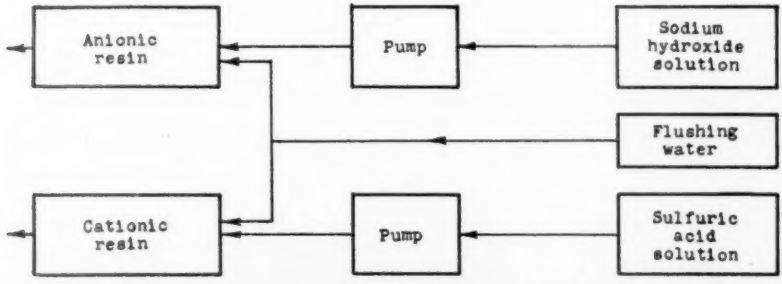

FIGURE 2.—Process regeneration cycle for plating rinse water treatment by ion exchange.

TABLE I.—Compositions of Acid Copper Plating Solutions

Component	Concentration (oz./gal.)	
	Sol. 1	Sol. 2
Copper (Cu)	0.0375	0.0375
Copper sulfate ($CuSO_4 \cdot 5H_2O$)	0.15	0.15
Sulfuric acid	0.038	0.038
Molasses	0	0.006
Thiourea	0	0.000012

not eliminated, by pretreatment of the influent to the resin beds.

The fact that the presence of relatively small quantities of organics can affect or alter the results makes it mandatory that specific consideration be given to all the materials present, and that loose terminology be avoided.

The effect of organics can be illustrated by the volume-to-resin-exhaustion findings with respect to two types of rinse waters from acid copper plating solutions. The first, a standard or dull acid copper plating solution, passed 166 gal. through the resin before it became exhausted. The second, a bright acid copper plating solution, only passed 100 gal. Both solutions were treated with the same size resin (IR120) bed. The solutions were made up as shown in Table I.

It is advisable to bring all rinse waters of a common type to a single collection point for deionization treatment (see Figure 1). Waters from nickel plating operations would be in one collection tank, and those from chromium plating locations in a second common collection tank.

The first resin contacted by the rinse waters should be that which removes the particular metal ion present in the plating solution. This eliminates the possibility of precipitating the metal in the resin bed, and thereby creating unnecessary interference with the ease of operation.

Chemical behavior should also be taken into consideration with respect to regeneration procedures. An illustration of this point would be the regeneration of a cationic bed which had removed calcium. If in the plant process, sulfuric acid is desirable as the regenerant, one would have to anticipate the precipitation of calcium sulfate within the resin bed. To avoid or minimize such an occurrence, it is necessary to use a two-stage regeneration treatment with varying acid concentration and widely different flow rates.

Illustrative Problems

The equipment, process requirements, and cost factors for treating three selected rinse waters—chromic acid, nickel, and acid copper—are outlined in the following examples:

Chromic Acid

Problem

Volume of waste H_2CrO_4 rinse to be treated daily	24,000 gal.
Concentration of H_2CrO_4	0.036 oz./gal. (270 p.p.m.)
Total weight of H_2CrO_4 to be removed daily	53.5 lb.

Method

	Anionic Resin (Anion Exchanger) IRA 410	Cationic Resin (Cation Exchanger) IRA 120
Required Equipment and Capacity		
Exchange capacity, CrO_3 (oz./cu. ft.)	36	[1]
Bed size per column (cu. ft.)	6	6
Working flow rate per column (g.p.m./cu. ft.)	5	5
Actual flow through column (g.p.m.)	30	30
Amount of CrO_3 removed per column at exhaustion (oz.)	216	None[1]
Volume put through bed at exhaustion (gal.)	6,000	12,000
Regeneration		
Chemical required to regenerate bed	NaOH	HCl
Regeneration concentration (lb. regenerant/cu. ft. at 10%)	12	10
Regeneration volume per column per regeneration (gal.)	78	75
Required chemical per column per regeneration (lb.)	72	7.5[2]
Regeneration flow rate per cu. ft. resin (g.p.m.)	0.5	0.5
Volume of water required to flush resin beds at 5 g.p.m./sq. ft. (gal.)	480	600
Cycle		
Time for deionizing run (hr.)	3.34	6.68
Time for regeneration (hr.)	0.43	0.42
Time for flush (hr.)	0.27	0.33
Time for total cycle (hr.)	4.04	7.43
Number of cycles required to treat total volume	4	2
Time to treat total volume (hr.)	16.16	14.86

Summary of Water Volume Effect

Volume of water treated daily (gal.)	24,000
Volume of reclaimable regeneration solution from anionic resin (gal.)	312
Volume of regeneration solution from cationic resin and flush waters from both anionic and cationic beds discharged to sewage system (gal.)	3,582
Reduction of discharge to city sewage system (%)	85

Treatment Cost Data

At this point, the chromium has been reclaimed in the form of Na_2CrO_4. Two courses of action are now possible. One is to pass the Na_2CrO_4 through a cationic resin, which would replace sodium with hydrogen to form H_2CrO_4, which could be returned to the electroplating tank.

The second alternative is to precipitate the chromium as $BaCrO_4$, which can be sold. This latter treatment recovers the NaOH used as a regenerant, and no further expenditure is necessary for this latter chemical.

The economics of the situation may be illustrated by the following cost comparisons, which were determined by actual test runs:

[1] The bed size required for removal of cations is one-half of that required to remove the CrO_3 anion. However, for procedure standardization, a bed of size equal to the anionic resin was established, but will require only half the number of regenerations.

[2] Gallons of acid.

	Daily Cost or Recovery ($)	
	Conversion to Chromic Acid	Recovery and Sale as Barium Chromate
Value of H_2CrO_4 recovered from Na_2CrO_4 by ion exchange	13.25	—
Cost of HCl required to regenerate	24.18	4.68
Cost of NaOH for regeneration	14.83	—
Cost of $Ba(OH)_2$	—	15.62
Value of $BaCrO_4$ at 15¢/lb.	—	20.10
Daily loss	25.76	0.20

Nickel

Problem

Volume of waste nickel rinse to be treated daily	13,000 gal.
Concentration of nickel	0.02 oz./gal. (150 p.p.m.)
Total weight of nickel to be removed daily	16.2 lb.

Method

	Cationic Resin (Cation Exchanger) IRA 120	Anionic Resin (Anion Exchanger) IRA 410
Required Equipment and Capacity		
Exchange capacity, Ni (oz./cu. ft.)	17.5	(a)
Bed size per column (cu. ft.)	7.5	7.5
Working flow rate per column (g.p.m./cu. ft.)	5	5
Actual flow through column (g.p.m.)	37.5	37.5
Amount of nickel removed per column at exhaustion (oz.)	131	None[1]
Volume put through bed at exhaustion (gal.)	6,550	6,550
Regeneration		
Chemical required to regenerate bed	H_2SO_4	NaOH
Regeneration concentration (lb. regenerant/cu. ft. at 10%)	20	12
Regeneration volume per column per regeneration (gal.)	97.5	97.5
Required chemical per column per regeneration (lb.)	9.75[2]	90
Regeneration flow rate per cu. ft. resin (g.p.m.)	0.5	0.5
Volume of water to flush resin beds at 5 g.p.m./sq. ft. (gal.)	188	188
Cycle		
Time for deionizing run (hr.)	2.9	2.9
Time for regeneration (hr.)	0.43	0.43
Time for flush (hr.)	0.1	0.1
Total cycle time (hr.)	3.43	3.43
Number of cycles required to treat total volume	2	2
Time to treat total volume (hr.)	7	7

Summary of Water Volume Effect

Volume of water treated daily (gal.)	13,000
Volume of solution recovered by regeneration and returnable to plating tank (gal.)	195
Volume of regeneration solution from anionic resin and flush waters from both anionic and cationic beds discharged to sewage system (gal.)	730
Reduced water consumption (%)	94

Treatment Cost Data

Acid required per day (gal.)	19.5
Sodium hydroxide required per day (lb.)	180
Cost of acid per day ($)	7.78
Cost of sodium hydroxide per day ($)	9.27
Value of nickel sulfate per day ($)	19.49

[1] This bed is used to remove the phosphates, chlorides, sulfates, etc. The number of ions present was found to be sufficient to require a resin bed of the same size as that used to remove the nickel.

[2] Gallons of acid.

Acid Copper

Problem

Volume of waste acid copper[1] rinse to be treated daily	6,000 gal.
Concentration of copper	0.0375 oz./gal. (281 p.p.m.)
Total weight of copper to be removed daily	14 lb.

Method

	Cationic Resin (Cation Exchanger) IRA 120	Anionic Resin (Anion Exchanger) IRA 410
Required Equipment and Capacity		
Exchange capacity (oz./cu. ft.)	5	[2]
Bed size per column (cu. ft.)	9	9
Working flow rate per column (g.p.m./cu. ft.)	5	5
Actual flow through column (g.p m.)	45	45
Amount of Cu removed per column at exhaustion (oz.)	45	None[2]
Volume put through bed at exhaustion (gal.)	1,200	1,200
Regeneration		
Chemical required to regenerate bed	H_2SO_4	NaOH
Regeneration concentration (lb. regenerant/cu. ft. at 10%)	20	12
Regeneration volume per column per regeneration (gal.)	117	117
Required chemical per column per regeneration (lb.)	11.7[3]	108
Regeneration flow rate per cu. ft. resin (g.p.m.)	0.5	0.5
Volume of water required to flush resin beds at 5 g.p.m./sq. ft. (gal.)	270	270
Cycle		
Time for deionizing run (hr.)	0.45	0.45
Time for regeneration (hr.)	0.43	0.43
Time for flush (hr.)	0.1	0.1
Total cycle time (hr.)	0.98	0.98
Number of cycles required to treat total volume	5	5
Time to treat total volume (hr.)	4.9	4.9

Summary of Water Volume Effect

Volume of water treated daily (gal.)	6,000
Volume of regeneration solution from cationic resin returnable to plating tank (gal.)	585
Volume of regeneration solution from anionic resin and flush waters from both anionic and cationic beds discharged to sewage system (gal.)	3,300
Reduced water consumption (%)	45

Treatment Cost Data

Acid required per day (gal.)	59
Sodium hydroxide required per day (lb.)	576
Cost of acid per day ($)	23.06
Cost of sodium hydroxide per day ($)	29.66
Value of copper sulfate per day ($)	6.21

[1] General Motors formulation.

[2] This bed is used to remove the phosphates, sulfates, chlorides, etc. The number of these ions present was found to be sufficient to require a resin bed of the same size as that used to remove the copper.

[3] Gallons of acid.

WHITE WATER TREATMENT *

I. Factors Affecting Anaerobic Digestion

By Willem Rudolfs and Herman R. Amberg

Rutgers University, New Brunswick, N. J.

The principal liquid waste from a paper boardmill consists of water passing through the wires, showers, and felts of the paper machine. This waste, known as white water, contains varying amounts of fiber, size, dye, and loading material. Other sources of waste in the mill may be from beaters, regulating and mixing tanks, and screens.

For reasons of mill economy, conservation of water, and alleviation of stream pollution, increasing importance is attached to recirculation of water for re-use in the mills, and to treatment of waste discharged into receiving waters.

The strength of the waste discharged depends primarily upon the degree of recirculation. Recirculation results in a build-up of the dissolved organic material in the waste, and a considerable reduction in volume. This low-volume concentrated waste should lend itself readily to biological treatment.

To determine the feasibility of treatment of this highly pollutional waste by digestion, a study was made of some of the factors affecting the digestion process under batch and daily charge conditions.

Methods and Materials

Samples of white water were obtained from a paperboard mill utilizing chip board and waste paper. The samples were taken before the waste passed through a save-all, were screened through a 60-mesh screen to remove longer fibers, and were concentrated by evaporation to simulate "controlled closed" conditions.

The waste was concentrated from approximately 350 to 2,000 p.p.m. B.O.D. In concentration, a certain amount of coagulation of the solids takes place; the brown flocculant material settles rapidly (approximately 1,100 p.p.m. suspended solids). The concentrated waste was stored in the refrigerator at 5° C. to prevent decomposition.

The digesters consisted of 2- or 4-l. bottles, connected to gas collectors, with provision for removal of supernatant liquor or sludge. The inoculum used in the batch experiments was well-digested sewage sludge. For the daily addition experiments the acclimatized seed from the batch experiments was used, the daily additions being increased gradually until the desired loading was reached.

The average composition of 21 concentrated white water samples (Table I) shows that about one-half of the total solids consisted of volatile sub-

TABLE I.—Average Composition of White Water Concentrate

Determination	(p.p.m.)	(%)
Total solids	7,800	100.0
Total vol. solids	4,290	55.0
Total fixed solids	3,510	45.0
Dissolved solids	5,800	74.5
Suspended solids	2,000	25.6
Susp. vol. solids	1,090	14.0
Suspended ash	910	11.7
B.O.D. (5-day, 20° C.)	2,120	—
Total N	30.7	—
B.O.D./Vol. sol. ratio	0.495	—

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

TABLE II.—Effect of Concentration of White Water on Solids and B.O.D. Distributions

Determination	Waste as Received (p.p.m.)	Concentrated Waste			
		5 Times		10 Times	
		(p.p.m.)	Deviation (%)[1]	(p.p.m.)	Deviation (%)[1]
Total solids	1,288	6,848	+6.4	13,442	+4.4
Volatile solids	804	4,230	+5.2	8,248	+2.6
Dissolved solids	698	3,528	+1.1	6,832	−2.1
Suspended solids	590	3,320	+12.5	6,610	+12.0
Susp. vol. solids	420	2,150	+2.4	4,240	+0.9
B.O.D.	386	1,520	−21.3	2,850	−26.2

[1] Deviation from theoretical.

stances and that approximately 74 per cent of the total solids were in the dissolved state.

Effect of Evaporation on Solids Distribution

Because a considerable amount of the experimentation was conducted with white water concentrated by evaporation, it was necessary to determine its effect upon the characteristics of the white water, especially upon solids distribution and B.O.D. Table II shows that there is an apparent slight increase in the total solids, total volatile, and dissolved solids upon concentration, undoubtedly caused by errors inherent in the sampling procedure. Coagulation of colloidal material and possible adsorption of some of the inorganic material to this floc caused an increase in suspended solids. A decrease in B.O.D. occurred with concentration, probably caused by the

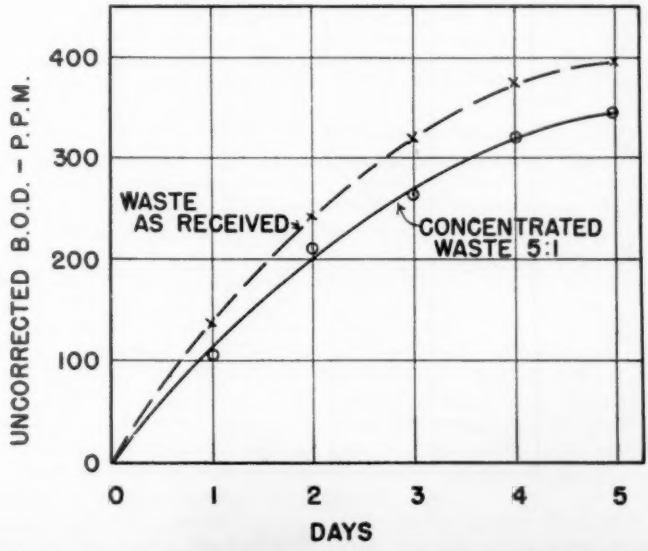

FIGURE 1.—Effect of time on oxygen utilization of concentrated white water waste.

volatilization of some of the volatile constituents.

The oxidation rate curves obtained by the Warburg method for the white water as received and the concentrated (5 times) sample are shown in Figure 1. The k and L values obtained from these rate curves, as well as the corrected B.O.D. values, were:

	Waste as Received	Conc. Waste (5 Times)
B.O.D., Warburg (p.p.m.)	431	1,865
B.O.D., dilution (p.p.m.)	386	1,520
k, Warburg	0.124	0.126
L, Warburg (p.p.m.)	549	460

The B.O.D. values obtained by the dilution method were considerably lower than the values obtained by the Warburg method. Although some of the B.O.D. was lost upon evaporation, it had no effect upon the k value. It appears that the concentrated waste should behave essentially the same as the original waste.

Effect of Inoculum Size on Digestion

In the decomposition of organic matter the most important single factor is inoculation of the raw waste with sludge that has undergone decomposition. Heukelekian (4) has found the optimum feed-to-seed ratio to be 2:1 (based on the weight of the volatile solids) in the digestion of fresh sewage solids.

To determine the feasibility of digestion of white water, and to determine the proper seeding ratios for optimum digestion, the following seeding ratios were used (concentrated white water to inoculum): 1:1, 2:1, and 4:1, based on the weight of volatile solids.

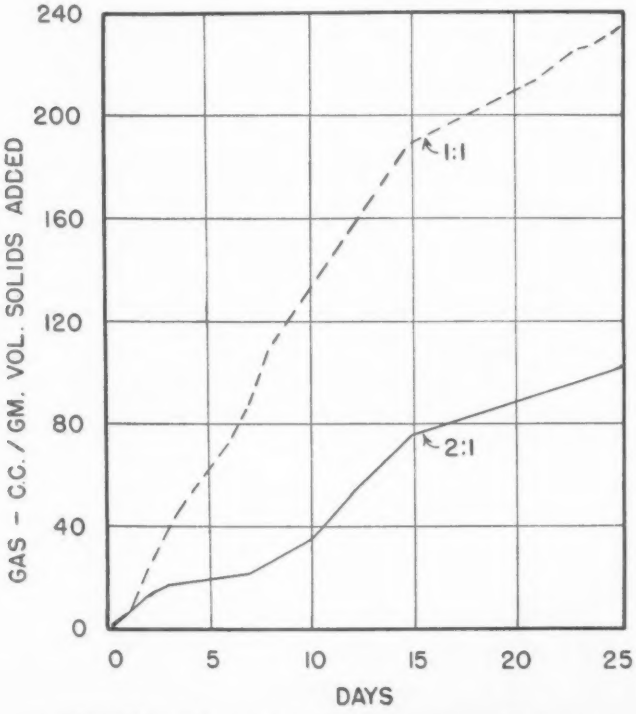

FIGURE 2.—Effect of size of inoculum on gas production.

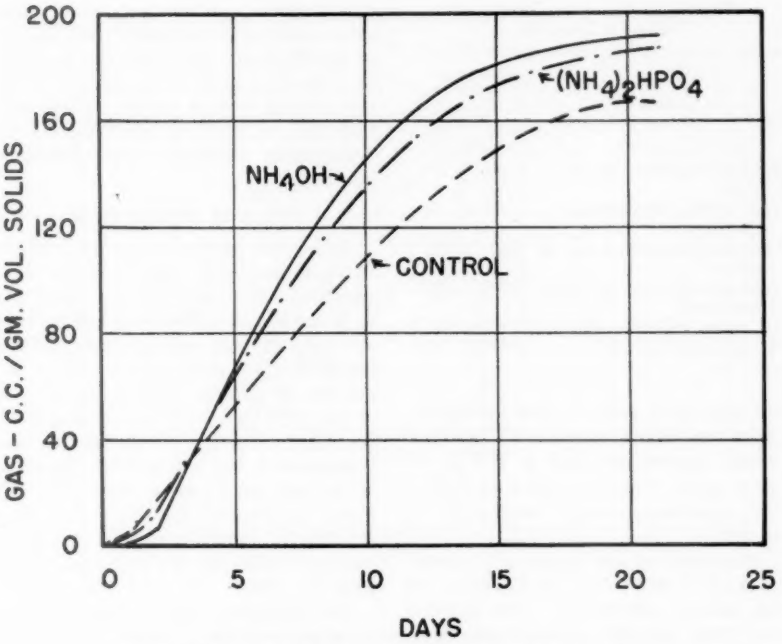

FIGURE 3.—Effect of nutrient addition on gas production.

A summary of the results (Table III) shows that a high degree of purification is possible by digestion. However, ratios of white water to seed in excess of 1:1 require long digestion periods for the stabilization of the organic materials. Cumulative gas production (Figure 2) emphasizes the effect of the size of inoculum. The gas production, in cubic centimeters per gram of volatile matter added, was found to be 260, comparing favorably with the average gas production obtained in the strawboard digestion experiment of Bloodgood and Hargboard (1). Compared to sewage sludge digestion, white water produced about one-third of the gas normally found.

Volatile matter destruction with a seeding ratio of 1:1 was about the same as with a seeding ratio of 2:1, but required less than one-half the digestion time, whereas a feed-to-seed ratio of 4:1 resulted in an initial lag period of 53 days before digestion started at a slow rate.

Effect of Nitrogen and Phosphorus Additions

Basically, all soluble organic wastes are amenable to biological treatment. However, because wastes lack sufficient phosphorus and nitrogen to maintain optimum biological growth, the waste must be fortified to produce good results. Buswell and Hatfield (2) found ammonia-nitrogen in the form of $(NH_4)_2CO_3$, NH_4Cl, or NH_4OH a suitable source of nitrogen for methane fermentation. An analysis of the concentrated white water indicated a deficiency in ammonia nitrogen, but the phosphorus content was sufficient to maintain a carbon-to-phosphorus ratio of 45.

To determine the effect of N and P upon the rate of digestion, ammonium hydroxide was added to one of the

TABLE III.—Summary Results on Effect of Inoculum

Item	Waste-to-Seed Ratio	
	1:1	2:1
Time of completion of run (days)	40	80
Time of 90% completion of run (days)	26	67
Total gas prod. (c.c./g. vol. sol. added)	261	257
Total gas prod. (c.c./g. vol. sol. destroyed)	488	500
Vol. solids destruction (%)	53.5	51.5
B.O.D. reduction (%)	90.3	90.9

digesters and diammonium acid phosphate was added to another. The white water concentrate had a B.O.D. of 2,270 p.p.m. The materials were seeded with ripe sewage sludge and incubated at 20° C.

Evolution of gas practically ceased at the end of 18 days of digestion for the control (Figure 3). The digester receiving NH_4OH reached the same peak in gas production at the end of 12 days; the digester with diammonium acid phosphate took 13 days to reach the same value.

Analyses of the effluents after 22 days of incubation (Table IV) and a summary of the results (Table V) show that artificial additions of ammonium salts materially increased the degree of purification. Although the residual ammonia-nitrogen of the effluent from the control was 30 p.p.m., it was not sufficient to give the same degree of purification resulting from nitrogen additions.

Effect of Temperature

Anaerobic decomposition of organic material is greatly influenced by temperature. The most notable variations in behavior at different temperatures are: (a) the rate of digestion or time required for stabilization, (b) the amount of material digested or amount of gas produced, and (c) the length of time lag. Rudolfs (6) found the best temperature for mesophilic digestion of sewage solids to be about 30° C. Temperatures up to 35° C. increase the rate of digestion slightly, but may be more difficult to maintain on a practical scale.

To determine the optimum temperature for the digestion of white water concentrate, three digestion temperatures, 20°, 30°, and 37°C., were employed. To ripe sewage sludge, white water concentrate (B.O.D. of 1,725 p.p.m.) was added, together with 25 p.p.m. N in the form of ammonium carbonate.

TABLE IV.—Analyses of Effluents from Mesophilic Batch Digestion at 20° C. with Nutrient Additions; Time of Incubation = 22 Days

Nutrient Addition	pH	Total Solids (p.p.m.)	Vol. Solids (p.p.m.)	Ash (%)	B.O.D. (p.p.m.)	NH_3-N (p.p.m.)
None	7.10	3,560	1,620	54.5	426	30.4
NH_4OH	7.20	3,260	1,280	60.7	306	117.0
$(NH_4)_2HPO_4$	6.90	3,220	1,220	62.2	300	129.0

TABLE V.—Summary of Results of Mesophilic Batch Digestion

	Control	NH_4OH Addition	$(NH_4)_2HPO_4$ Addition
Time of run (days)	22	22	22
B.O.D./nitrogen ratio	—	19.7	19.7
Destruction of vol. matter (%)	44.4	55.5	52.0
Gas prod. (c.c./g. vol. sol. added)	177	192	190
B.O.D. reduction (%)	81.3	86.4	86.8

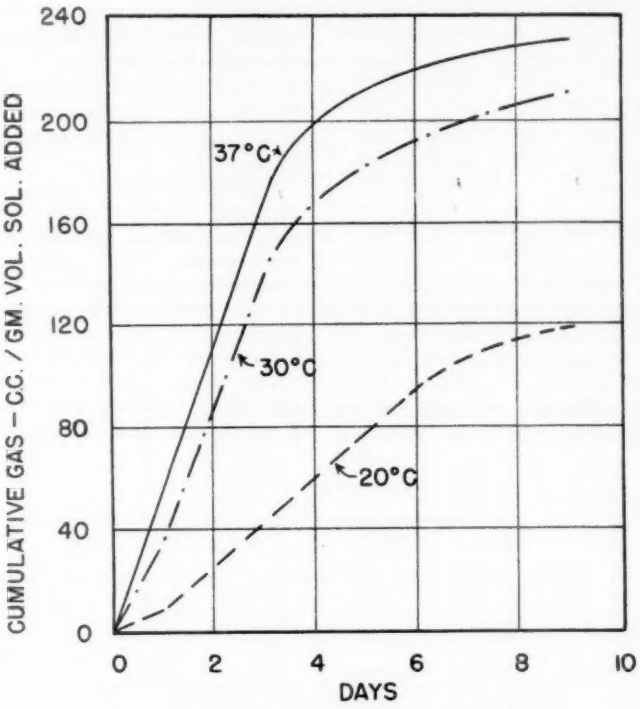

FIGURE 4.—Effect of temperature on gas production.

Accumulative gas production over a 9-day incubation period (Figure 4) shows that only one-half of the gas volume was produced at 20° C. as compared with that at 37° C., whereas at 30° C. 91 per cent of the 37° C. gas production was reached. A significant difference in volatile solids destruction was noted as the temperature of incubation was increased (Table VI). The data show that the rate of stabilization of the waste was affected by variations of the incubation temperature, but in a comparison of the 37° and 30° digesters on a B.O.D. removal basis, no significant difference was found. The higher rate of activity at 37° C. may be responsible for disintegration of sludge into finely divided colloidal material, which disperses in the supernatant liquor with the aid of evolving gas (Table VII).

Under optimum digestion conditions, gasification is practically complete in 9 days at a B.O.D. loading of approximately 9.7 lb. per 1,000 cu. ft. of digester capacity per day.

TABLE VI.—Effect of Temperature on Digestion

	Temp. (°C.)		
	20°	30°	37°
Time of run (days)	19	19	19
Vol. solids destruction (%)	34.8	40.0	46.5
Gas yield (c.c./g. vol. sol. added)	158	212	232
Gas yield, 9 days (c.c./g. vol. sol. added)	120	211	231
B.O.D. reduction (%)	79.1	80.2	77.5

TABLE VII.—Analyses of Effluents

Temp. (°C.)	pH	Tot. Solids (p.p.m.)	Vol. Solids (p.p.m.)	B.O.D. (p.p.m.)
20	6.70	3,520	1,480	361
30	6.80	3,120	1,160	342
37	6.90	3,300	1,340	388

Mesophilic Digestion of Daily Charges

Even under optimum conditions the performance of batch digestion is low, but experience has shown that continuous digestion with daily charges is much more efficient. In this study nitrogen additions were made and the daily loadings varied to determine whether the performance could be improved. Liquid NH_4OH was added to the daily feed additions to insure a B.O.D./N ratio of approximately 20. The digesters incubated at 30° C., with operating conditions as shown in Table VIII.

Volatile solids reduction (Figure 5) remained fairly constant over the range of loadings used. Gas production decreased with decreasing detention or increased loading. The pH values showed a slight decrease as the loadings were increased, but the reaction did not drop below 6.92.

The effluent withdrawn daily was light green. A strong odor of H_2S persisted throughout the digestion period,

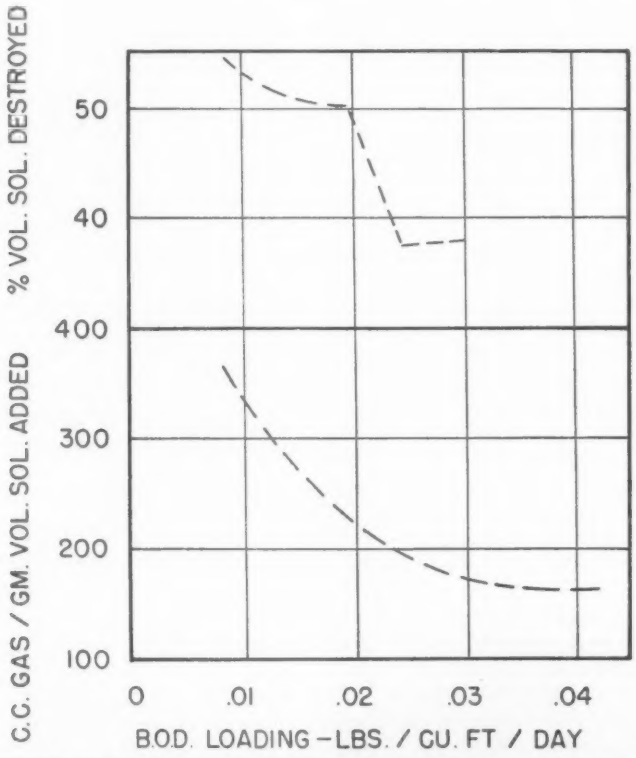

FIGURE 5.—Relation between B.O.D. loading and volatile solids destruction, and gas production.

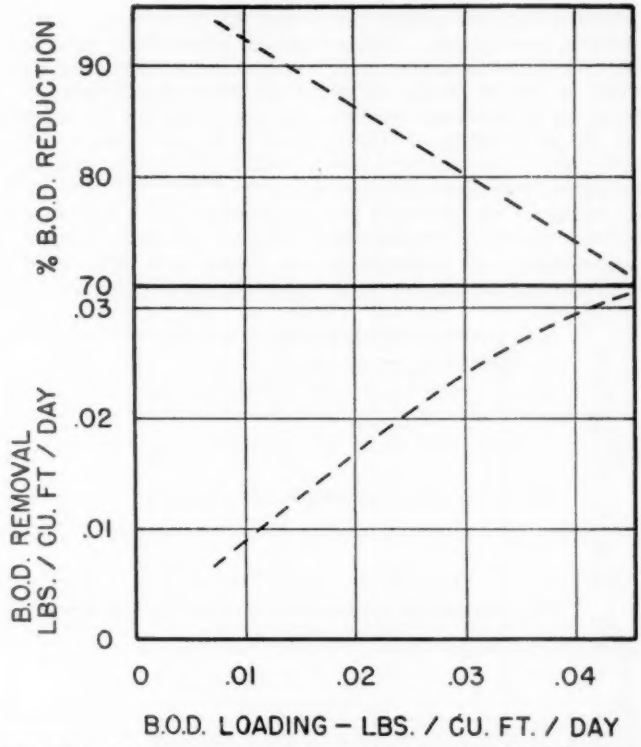

FIGURE 6.—Relation between loading (daily charges) and B.O.D. removal.

and the B.O.D. of the effluent increased with increased loading. The percentage B.O.D. reduction decreased as shown by the average analyses of the effluents. (Table IX).

It appears that the percentage B.O.D. reduction is a linear function of the applied B.O.D. load, and in terms of actual pounds removed per unit of digester capacity the same general relationship holds (Figure 6).

The sludge build-up was considerable for the mixtures subjected to 5- and 4-day detention periods; the in-

TABLE VIII.—Operating Conditions; Mesophilic Digestion with Daily Charges

Detention (days)	Sludge Volume (ml.)	Vol. Solids in Sludge (g.)	Daily Change (ml.)	B.O.D. Loading (lb./cu. ft./day)	Length of Run (days)
16	1,500	31.25	100	0.00859	33
11	1,500	31.25	150	0.01250	33
7	1,500	31.25	250	0.01960	33
5	1,500	34.35	375	0.0244	23
4	1,500	34.35	500	0.0305	23
3	1,000	30.50	500	0.0437	16

TABLE IX.—Analyses of Effluents; Mesophilic Digestion with Daily Charges at 30° C.

Detention (days)	pH	Total Solids (p.p.m.)	Vol. Solids (p.p.m.)	Ash (%)	B.O.D. (p.p.m.)
16	7.33	3,130	1,380	55.9	178
11	7.30	3,420	1,500	56.1	212
7	7.25	3,740	1,650	55.9	267
5	7.19	3,340	1,680	49.7	363
4	7.13	3,350	1,640	51.0	398
3	6.92	3,400	1,700	50.0	609

crease in total solids, over a 23-day digestion period, was material. Assuming a sludge concentration of 4 per cent, about 6,320 cu. ft. of sludge would be produced per m.g. of waste treated, or 395 cu. ft. per 1,000 lb. of B.O.D. applied.

A high degree of purification is possible with relatively long detention periods, but the degree of purification decreases gradually with increases in loading. Total gas production averaged 3.2 cu. ft. per pound of volatile matter added (3-day detention), which is low compared with gas production from sewage sludge digestion, probably because of the low fat and grease content of the paper waste.

Two-Stage Digestion

Considerable work has been published on two-stage or series digestion of wastes with high B.O.D. values. Buswell and LeBosquet (3) have stud-

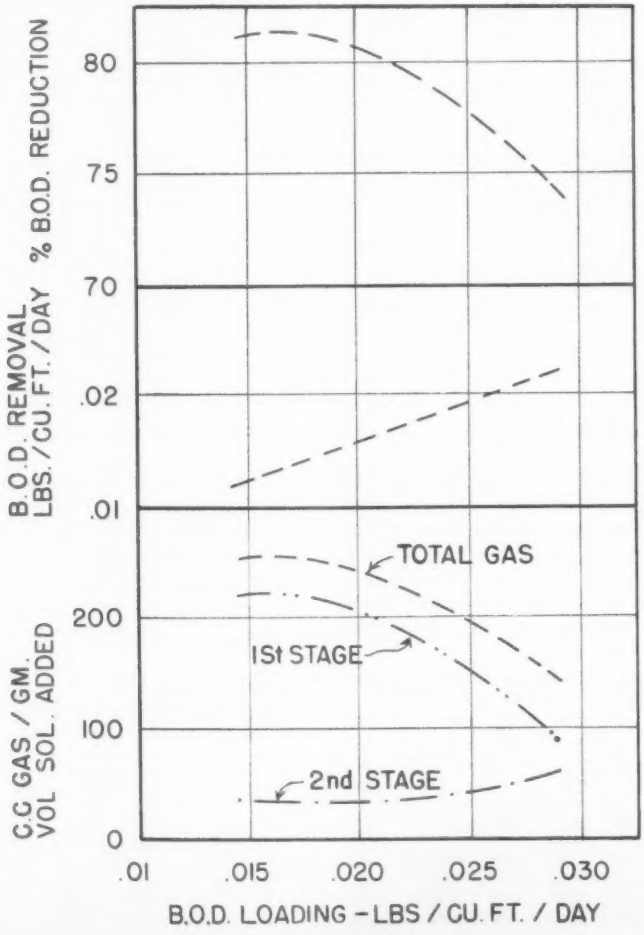

FIGURE 7.—B.O.D. removal and gas production with two-stage digestion.

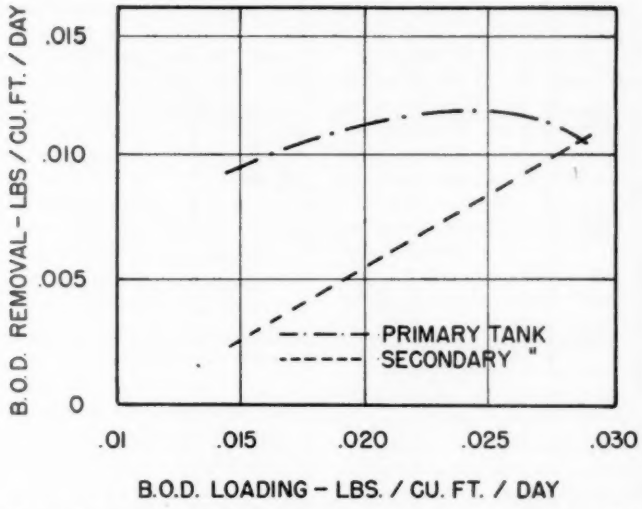

FIGURE 8.—Comparison of B.O.D. reduction in primary and secondary digestion.

ied treatment of distillery waste and Rudolfs and Trubnick (5) described a two-stage plant for the digestion of compressed yeast waste in which consistently higher removals at all loadings were effected, compared with one-stage or parallel operation of the digesters.

A two-stage mesophilic system to de-

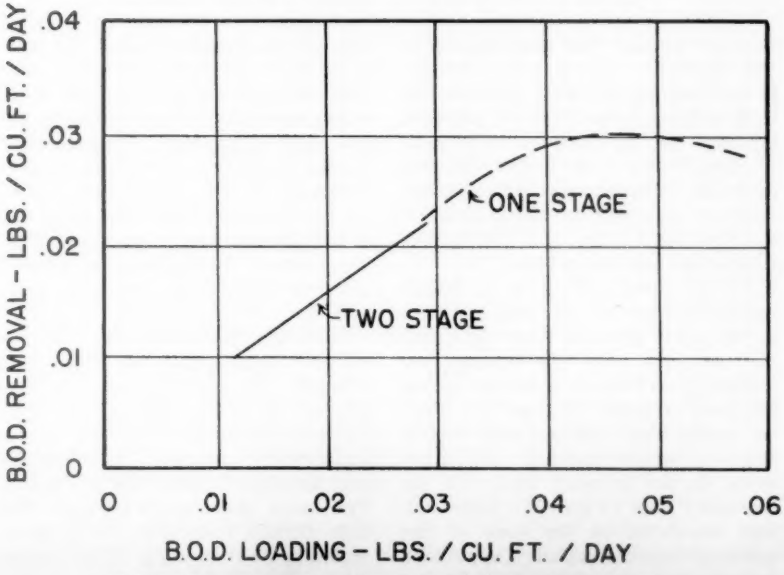

FIGURE 9.—Comparison of one-stage and two-stage digestion.

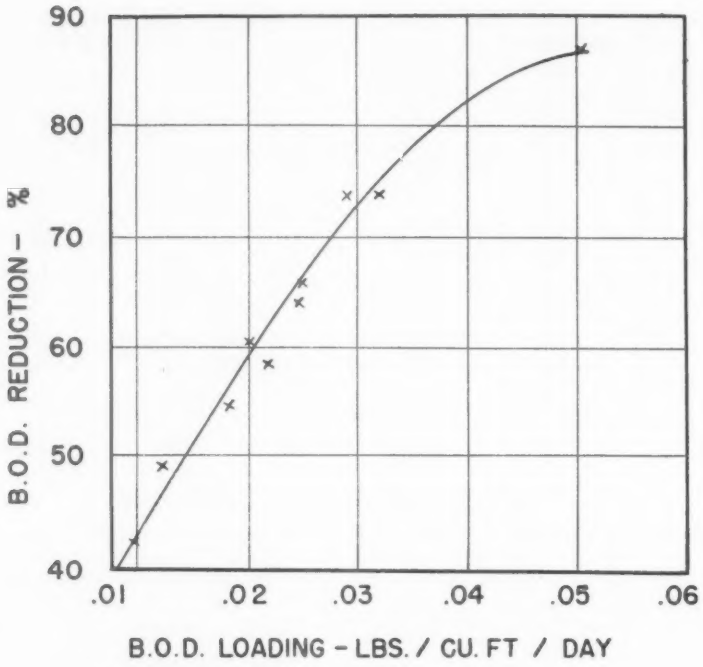

FIGURE 10.—Effect of B.O.D. loading on B.O.D. reductions.

termine whether the performance of the digestion process could be improved was set up with detention periods varying from 8⅔ to 4⅔ days and loadings varying from 0.0144 to 0.029 lb. B.O.D. per cubic foot of digester capacity. Nitrogen was added as ammonium carbonate to the influent of the first stage only, and a B.O.D./N ratio of 20 was maintained.

No significant differences in B.O.D. reduction were found with loadings up to about 0.022 lb. per cubic foot per day, but when the loading was increased, a decided decrease in the efficiency occurred (Figure 7). Similar results were obtained with volatile and total solids removals. B.O.D. removal in the primary tank and the secondary tank (Figure 8), with loadings calculated on the basis of the combined digester capacity, appears to indicate that series operation did not improve the performance of the digestion, but a comparison of single-stage and two-stage operation (Figure 9) shows that the two-stage digester had not received maximum loading. With increased loading a break in the performance of the single-stage unit occurred between B.O.D. loadings of 0.04 to 0.05 lb. per cubic foot per day. Once the primary unit became overloaded, the over-all efficiency was greatly impaired.

Although batch digestion was less efficient than digestion with daily charges, it afforded an excellent method for the determination of the optimum digestion conditions, such as temperature, nutrient requirements, and the approximate rate of feeding. The batch experiments revealed that high B.O.D. reductions could be attained in 10 to 15 days. When sewage sludge was used as inoculum, a seed-

ing ratio of 1 part ripe sludge to 1 part white water on the basis of volatile matter was adequate to insure rapid digestion, but when this ratio was decreased an appreciable lag period resulted. The optimum temperature for mesophilic digestion appears to be between 30° and 37° C. Because the feed is deficient in nitrogen, some form of nitrogen must be added. Under optimum conditions 80 per cent of the B.O.D. can be reduced approximately 10 days by utilizing batch digestion with an applied B.O.D. load of about 0.01 lb. per cubic foot of digester capacity per day.

A combination of daily feed additions and nitrogen supplements results in a two-fold increase in the B.O.D. load. Depending on the form in which the nitrogen is used, costs vary considerably. Since ammonium hydroxide is lowest in cost per pound of N, it was used in the experiments.

A plot of all single-stage experiments conducted at 30° C, shows that B.O.D. reduction in terms of actual pounds removed per unit of digester capacity per day is a linear function of the B.O.D. load up to 0.04 lb., but with higher loadings the linear relationship between loading and reduction of B.O.D. does not appear to hold (Figure 10).

Conclusions

The results presented warrant the following conclusions:

1. Concentration of white water by evaporation does not materially change the characteristics of the waste.

2. The optimum temperature range for the meosphilic digestion is between 30° and 37° C. At 37° C. a higher rate of gasification can be expected, but no significant improvement in B.O.D. reduction.

3. White water is deficient in nitrogen. Ammonia-nitrogen in the form of $(NH_4)_2CO_3$, NH_4OH, or $(NH_4)_2HPO_4$ can be added as a suitable source of nitrogen for anaerobic digestion.

4. At 30° C., with an applied B.O.D. load of 0.044 lb. per cubic foot of digester capacity per day, a B.O.D. reduction of 71 per cent and total and volatile solids reduction of 52 and 61 per cent, respectively, can be expected.

5. Approximately 3.2 cu. ft. of gas per pound of volatile matter added will be produced.

6. At lower loadings, two-stage or series operation of the digesters shows no improvement over parallel operation of the digestion system.

7. For practical purposes, anaerobic digestion is effective for the removal of approximately 70 to 80 per cent of the applied B.O.D. load. When higher reductions are desired, extremely long detention periods are required.

Summary

For reasons of mill economy, conservation of water, and alleviation of stream pollution, increasing importance has been attached to the recirculation of paper mill water for re-use in the mills, and to subsequent treatment of the waste portion to be discharged. Recirculation results in a build-up of the dissolved organic material in the waste and considerable reduction in volume. To determine the feasibility of treatment of this concentrated low-volume waste by digestion and to indicate the effect of various environmental factors (temperature, nutrient additions, and variation of the seeding ratio), batch digestion experiments were conducted, whereas the optimum loadings were determined by digestion of daily charges.

For practical purposes, anaerobic digestion for 4 to 5 days is effective for the removal of approximately 70 to 80 per cent of the applied B.O.D. load, provided some nitrogen is added and the material is digested at about 30° to 35° C. When higher B.O.D. reductions are desired, longer detention periods are required.

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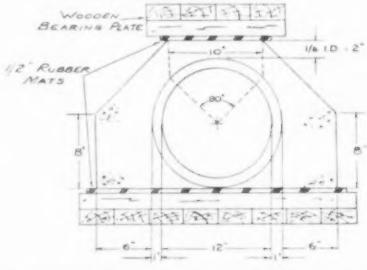
TEST STRENGTHS OF ARCH-ENCASED PIPE

Under the above heading, H. W. Jewell, of the National Sewer Pipe Company Ltd., of Canada, recently made a preliminary report on tests conducted on pipe of less than 24-in. diameter with arch encasement. The study was undertaken because of the high cost of "under pipe" cradles, the limitations of sidewall cradles, and the lack of data for arch encasement of small diameter pipe.

The pipes were tested to failure by the arrangement shown in the accompanying sketch. Samples tested included 4-, 12-, and 24-in. diameter pipe. A ½-in. thick rubber mat was placed under the test unit and under the bearing plate to more closely approximate trench loading conditions.

Observations during the tests of the action on the 12-in. and 24-in. encased sections during loading and at failure show that the pipe and encasement act as a unit and failure occurs simultaneously at the center of the upper arch and at one or two quarter points in the upper arch section. The encasement appears to act as two stiffening legs on each side of the pipe, carrying the load to the subgrade. The test results are high and indicate that some lesser material from the standpoint of cost and strength might supply adequate supporting strength.



Test arrangement for 2-in. arch encasement of 12-in. concrete pipe.

WASTE DISPOSAL AT THE FONTANA STEEL PLANT*

By H. I. Riegel

Superintendent, Utilities Department, Kaiser Steel Corporation, Fontana, Calif.

Waste disposal and water conservation are so closely related that it is impossible to segregate one from the other. To reduce or eliminate water pollution is to make this recovered water available for further use. By so doing, the need for fresh supply is reduced, thereby conserving one of the country's greatest material resources. During the past 10 to 20 yr., widespread interest in water conservation has developed throughout the entire country. On the West Coast there has been an awareness of the importance of water to the region's economy for a much longer period because of the scarcity of water in the developed areas. There has probably been more material published about water and water pollution in the past 10 years than was published in the previous 100 years. More will be heard on this subject as the national economy increases and the need for conservation becomes greater. Good planning can and will conserve this valuable and necessary resource for future generations. Many people will have to change from the thinking of a wasteful economy to that of conservation.

The waste disposal problem at the Fontana plant of Kaiser Steel Corporation is so clearly tied in with the general water problem that it is impossible to discuss one without including the other. Before presenting a discussion of the problem of water and waste, some background is necessary for those not familiar with the Fontana plant and area.

* Presented at 1952 Annual Meeting, California Sewage Works Association; Santa Cruz, Calif.; April 23–26, 1952.

No Nearby Water

The Fontana plant is probably the only fully integrated steel plant not located at or near a river, ocean, or lake to supply the required large volume of water for the steelmaking processes; or on a river or outfall to dispose of used water. This plant, therefore, is faced with a water problem which few other steel mill operators worry about. At Fontana, approximately 50,000 gal. of water are recirculated for every ton of steel shipped out. This recirculation requires approximately 2½ per cent make-up or 1,400 gal. of actual consumption per ton of steel produced. The national average for other mills is approximately 65,000 gal. per ton of steel shipped. As most other mills have little or no recirculation, this makes their actual consumption 65,000 gal. per ton, compared to the Fontana plant consumption of 1,400 gal. per ton.

It is not the intent of this paper to tell the personnel of other industrial plants the means by which they can conserve water or control pollution. It is hoped simply that it will stimulate interest to review water and pollution problems. However, some of the details of procedure may be applicable to other plants. Variables will be the quality of water received, the nature of the processes and their effect on the quality of water, and finally the requirements for effluent quality.

The Fontana plant purchases water from a local water company, which is essentially a supplier of irrigation water. This is raw untreated water received from Lytle Creek, from wells in the Lytle Creek basin, and from wells

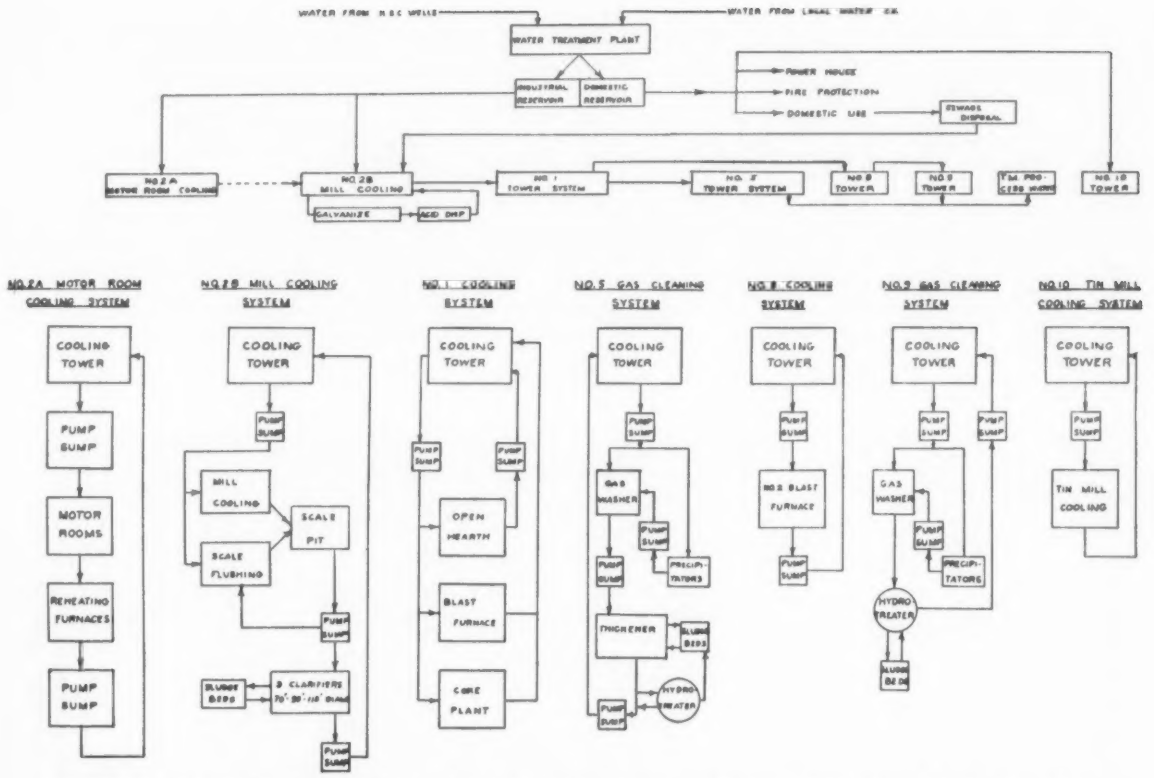


FIGURE 1.—Schematic layout of water supply and recovery system at Fontana, Calif., plant of Kaiser Steel Corp.

in the Chino basin. Lytle Creek is a small mountain stream, the flow varying with snow and rainfall in a relatively small watershed. The creek normally supplies a large percentage of the water company's requirements during the late winter and early spring months, but becomes grossly inadequate during the remainder of the year, when agricultural and domestic requirements reach a peak. The water company supplements the creek flow with well water.

The steel plant also has two wells on the plant property, which are used to supplement the outside source of water. The water level is approximately 350 ft. below the ground surface.

With the conditions as outlined, it is apparent that many problems could be expected. Many of the problems were overcome by recognizing them before the plant was built and incorporating conservation measures in the basic design. Many other problems were handled in plant operations as soon as they were recognized as being important. This required changes of design, changes in operation, and involved experiments on unproven theories. The measures taken, combined with a plant-wide educational program, have resulted in low water consumption and excellent control of industrial wastes.

A study of the Fontana plant water system (see Figure 1), shows that every operation is carried on in such a manner as to conserve water and control the pollution problem. Some of these operations may appear trivial, but they are all part of the over-all plan.

Raw Water Treatment

The raw water enters the water treatment plant (Figure 2), where it is treated in a 50-ft. diameter hydrotreater with pebble lime and soda aluminate. Sludge is continuously recirculated to aid in the reduction of solids. The water then passes to a carbonation basin, where the resultants of combustion are bubbled through the water to control the pH, and then through a rapid sand filter to the covered domestic water reservoir. It will be noted that an attempt is made to remove solids rather than change the salts for softening only.

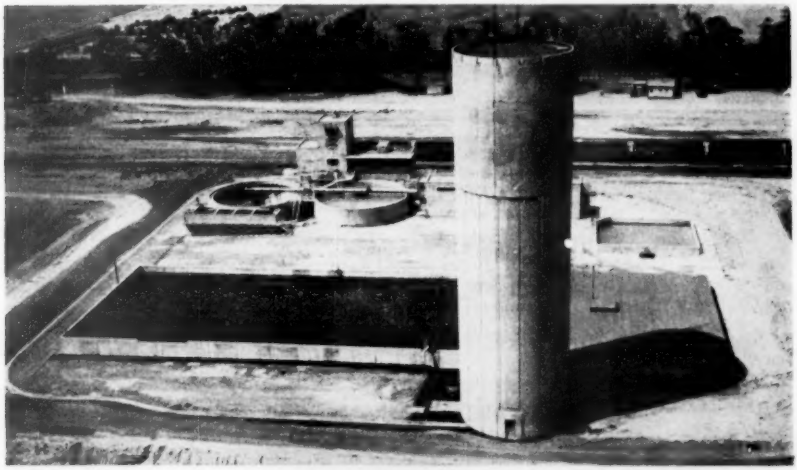


FIGURE 2.—Water treatment plant, with domestic (covered) and industrial reservoirs in foreground.

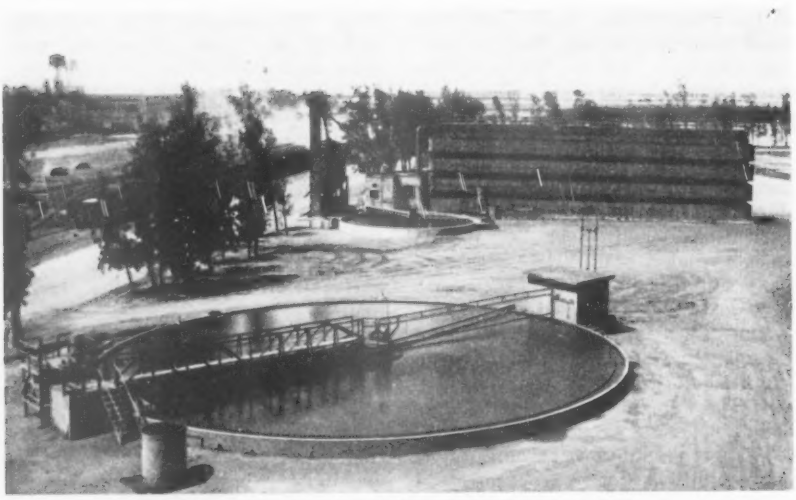


FIGURE 3.—No. 5 tower of blast furnace washing system.

The domestic water reservoir normally overflows into the industrial reservoir. Occasionally, water from the hydrotreater passes directly to the industrial reservoir without the benefit of passing through the sand filters. It is preferred to pass all water through the sand filters, but emergency conditions sometimes prevent this.

The sand filters are backwashed once daily under normal conditions. Backwash water is delivered to a reclamation basin, where the solids are allowed to settle out for 4 to 6 hr. The solids, as sludge, are delivered to a sludge bed, and the water is returned to the system in the carbonation basin for use.

The domestic water system consists of pumps in the domestic reservoir, which deliver water into the domestic mains with a 250,000 gal. tower. The domestic mains form a network to supply water for fire protection, human consumption, and sanitary purposes. This network also supplies water for lawn and shrubbery irrigation around buildings. It is not used for the general agricultural enterprises conducted on some 700 acres of the plant property. This latter water is raw water as purchased and supplied through a separate irrigation line.

Successive Uses of Water

The industrial reservoir supplies the industrial consumers through a separate system. Normal procedure is to make up water into the 2A system, blow down into the 2B system and from 2B system to the No. 1 tower, and finally into the blast furnace gas washing system. The blow-down from the blast furnace gas washing system supplies the slag pits with the water needed to cool the slag sufficiently to be handled by mechanical equipment for removal to the slag dump. The blow-down of one system is the supply for the next system.

The 2A cooling tower system, consisting of cooling towers and pumps, has a capacity of 15,000 g.p.m. This water is pumped to the motor rooms for cooling both the rooms and the electrical equipment, including the 5,000-h.p. motors. It then passes through the water-cooled skids of the reheating furnaces and discharges into a pump sump, from where it is pumped over the cooling towers to start another cy-

cle. Threshold amounts of phosphate are used to control scale conditions in this system.

The 2B system (Figure 4) consists of one natural-draft cooling tower with necessary pumps. It supplies water for cooling the bearings and rolls of the various rolling mills. At the mills, some of the water is recirculated to move the scale into the scale pit, where the scale may be recovered to be reintroduced into the metallurgical process for recovery. The heat load on this system is low, but the volume of water used is very high. As this water carries considerable suspended solids and some lubricating oil, three clarifiers (70-ft., 90-ft., and 115-ft. diameter) have been installed to settle the solids from the water and also skim the oil. The water returned from the mills passes through these clarifiers in parallel into a pump sump, where part of the water is pumped over the tower for cooling. The remainder passes over the overflow and is combined with effluent of the cooling tower to supply the main pump house with the water required by the mills. This system also has a traveling screen to remove leaves and other material that may be blown into the cooling towers. Equipment has been provided to add coagulating material to the water as it enters the clarifier. Coagulating material is not used at present.

The No. 1 system is identical in operation to the 2A system previously mentioned, in that the water passes over cooling towers to a pump sump, where it is pumped into the supply lines for open hearth furnace, blast furnace, and coke plant cooling. In most cases, where practical, a number of coolers are placed in series to reduce the water requirements. It has been found that by so doing the water consumption is less, the cooler losses are less, and better operation of the cooling system is obtained, due to the

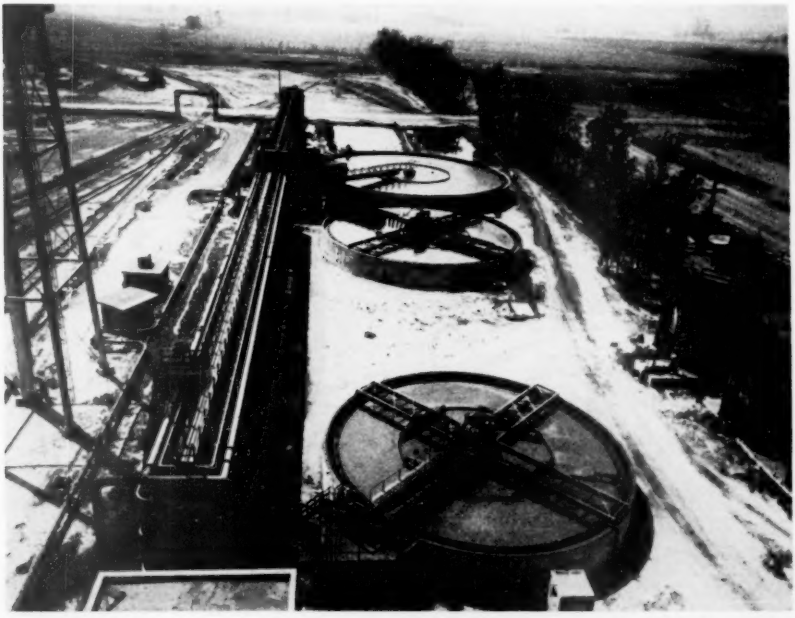


FIGURE 4.—2B cooling tower system with clarifiers to remove solids and skim off oil.

greater heat differential available. This higher velocity also permits higher concentration of solids with less loss of coolers. In many cases it has been found necessary to redesign coolers to increase the velocities, thereby reducing loss of coolers because of scale build-up. No chemical treatment is used in this system.

The gas washing system (Figures 5 and 3) receives the blow-down of the rest of the system. It washes dirt from the blast furnace gas so that the gas may be burned in furnaces without the flue gas passages becoming plugged with dirt. It also reduces dust liberated into the air with the flue gases. As the water becomes very poor after passing through the system two or three times, it is necessary to incorporate water treatment at this point. The water is heavily laden with solid materials from the dust of iron ore, coke, and limestone; soluble material, such as CO_2 from the gas; calcium bicarbonate; magnesium bicarbonate; and smaller amounts of potassium and sodium compounds. It is necessary to remove sufficient of these materials to render the water suitable for re-use and at the same time dispose of any surplus in a manner that will not jeopardize the underground water stream. A 90-ft. diameter thickener has been used for settling the heavier solids; a mixture of soda aluminate and alum has been used recently to form a floc to further improve the cleaning. After the water passes through the thickener, part of it passes through a 50-ft. hydrotreater, where the water is treated with pebble lime for reduction in solids. Some water from this system is used to cool the blast furnace slag so that mechanical equipment can handle it for removal to the slag dump. This water requirement acts as a blow-down for the gas washing system.

Sewage Disposal System

A network of sanitary sewers covers the plant area. These sewers terminate at a complete two-stage bio-filtration sewage treatment plant (Figure 6) on the company property. The sewage

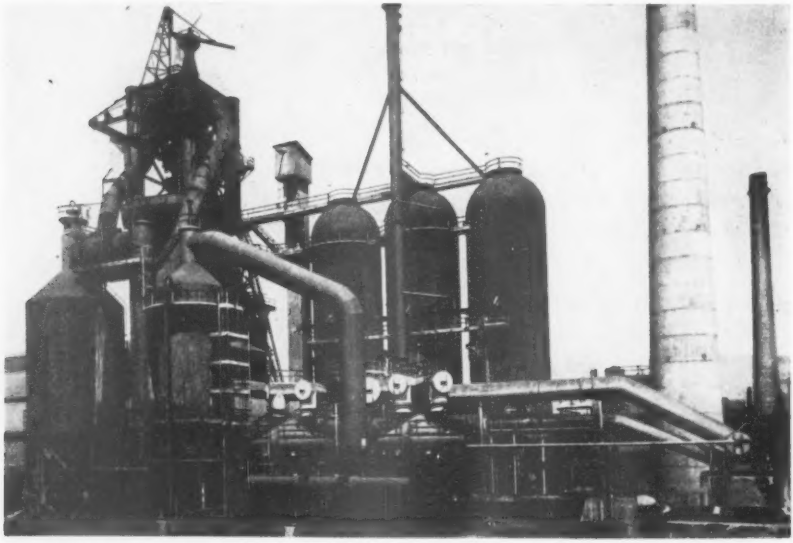


FIGURE 5.—Blast furnace gas washing system, with blast furnace in background.

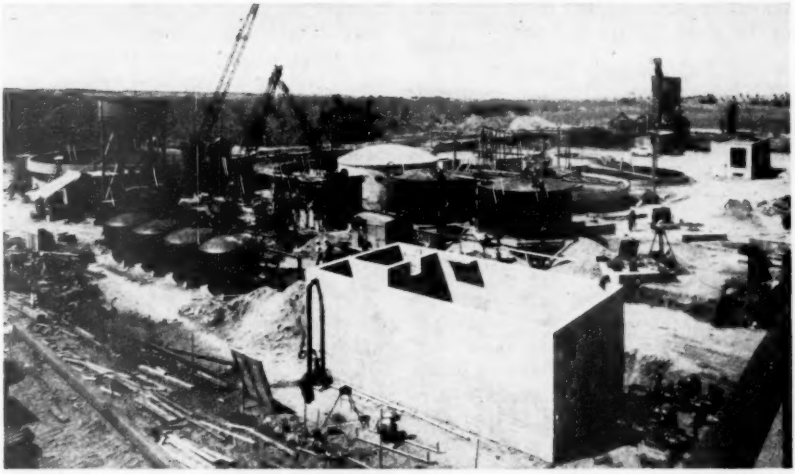


FIGURE 6.—Sewage disposal plant, with acid disposal plant in background and tin mill water system under construction in foreground.

passes through a grit removal channel, two comminutors, and a Parshall flume, into an influent well. It is then pumped into a 110,000-gal. primary clarifier 50 ft. in diameter. The sludge is pumped from the bottom into a covered sludge digester and the liquid overflows into a flume, which carries it to a primary bio-filter 50 ft. in diameter by 3 ft. deep (218 cu. yd.) The effluent of this filter is delivered to a recirculation well where part is returned to the influent well for recirculation to the primary circuit. The remainder is pumped into the secondary settling tank. Part of the settling tank effluent is returned to the secondary filter and the remainder to the helical baffled chlorination basin.

This basin is 30 ft. in diameter by 7 ft. deep, and from it the water is pumped into the industrial water system for further use. Chlorine is supplied by two chlorinators having a capacity of 100 lb. per day each.

Sludge beds are available for retaining digested sludge from the digester. Sludge removal is required once every 12 to 18 months.

Acid Disposal

Certain steel products must be treated for removal of surface blemishes and defects, including rust and scale, preparatory to sale or further processing. Pickling with acid is used for some of this work. The spent acid must be neutralized so that water may be recovered.

Spent acid is delivered by ceramic pipe lines to a lead-lined steel storage tank. The spent acid is pumped from this tank into the first of a series of three wooden turbo-mixer tanks 14 ft. in diameter by 10 ft. deep. Each tank (Figure 6) is equipped with a motor-driven impeller for mixing, and submerged air lines for aerating. The acid enters the first turbo-mixer, where pebble lime is added. The overflow from the first tank passes into the second tank and from the second to the third. Part of the effluent of the third turbo-mixer is pumped to the first turbo-mixer for recirculation. The surplus overflows into a 50-ft. diameter thickener, from which the sludge is pumped to sludge beds and the water is sent to the chlorinator basin of the

sewage treatment plant to be returned to the plant for further use.

Quenching Tower

The coal received contains a certain amount of moisture, some of which is liberated to the gas in the coking process. As the gas passes through the by-products recovery plant, the moisture is condensed out and recovered. This moisture, unsuitable for ordinary industrial cooling without expensive treatment, is collected in a sump for use in quenching of coke. Coke removed from the coke ovens has a very high temperature and if allowed to air cool would burn when exposed to air. It is therefore necessary to cool this coke rapidly. The recovered water is pumped over the coke, the overflow being returned to the pump sump for further use. As a result of this recovery operation, very little if any plant water is used for make-up.

The water in this system is evaporated in the quenching process, leaving the residue on the coke, which is later charged into the blast furnace. Any objectionable material is either burned and passes out with the blast furnace gas, or is removed as part of the blast furnace slag and delivered to the slag dump. The blow-down water from the blast furnace gas washing system and the rinse water from zeolite softeners is sprayed on the molten slag and is evaporated, also leaving the solids with the slag. The solids apparently fuse with the slag, as tests of the resultant blast furnace slag indicate no ill effect because of possible leaching.

Tin Plate Water

A new tin plate mill about to be placed in operation at Fontana introduced some new problems. In cooperation with Kaiser Engineers, a new water system was designed to take care of the problems. The system will receive water from the blast furnace gas washing system and treat it in such a manner as to make suitable water for tin mill use. The system also will treat the spent pickle liquor from the tin plate mill operations and recover the water for further use. This system is designed to handle 600 g.p.m. of process water and recirculate 7,000 g.p.m. of cooling water. The $350,000 cost may seem like a heavy capital expenditure for the volume of water handled, but it must be remembered that there is no place to dispose of this water and thought must always be given to protection of the underground water reserves.

Control Testing

A comparison of the company's water department costs with those of similar steel mills indicates a slight disadvantage. In this respect, operating costs at Fontana are necessarily higher because of multiple pumpage and chemical treatment. Also the capital investment naturally is greater. The system as now constituted requires six men continuously for operations. These are some of the penalties involved because of the plant's location. However, there are some advantages, in that water quality control generally is better and fish or rubbish do not enter water intakes to play hob with the systems.

Control of water quality is maintained by tests that have been found necessary or desirable. The testing is done by the operators on a periodical basis. The time interval between tests is based on the need for control; many are hourly tests, some daily. The record of these operating control tests gives a guide to performance and supplies a clue to abnormal conditions which may require special attention.

In addition, weekly check tests are made by the chemical laboratory to verify the operators' results and supply supplemental data unobtainable by the operators. When necessary, additional tests are made by the labora-

tory to provide data for special situations.

The plant could not be expected to maintain water or pollution control without the minimum testing procedure that has been in use.

Summary

Water conservation and pollution control as practiced at the Fontana plant of Kaiser Steel Corporation are the results of a number of factors, as follows:

1. Location of the plant in a water-scarce area.
2. Location of the plant without a stream or body of water in which to discharge plant effluent.
3. A good basic design of water system with flexibility available to change pattern of operations as conditions warrant.
4. An alert management that recognizes the need to conserve resources and is willing to do something about it.
5. An organized test procedure.

ILLINOIS SEWERAGE SUMMARY 1880–1950

An interesting comparison of the growth of sewer service and treatment of municipal sewage in Illinois is given in a recent summary prepared by the Illinois Sanitary Water Board. The data are given in the accompanying table. It should be noted, however, that the data are for municipal sewage only, the population equivalent of industrial wastes not being reflected.

Year	Illinois Population			Per Cent Total Population		Per Cent Sewered Pop. Trib. to Sew. Treat. Works
	Total	Trib. to Mun. Sewers	Trib. to Mun. Sew. Treat. Works	Sewered	Trib. to Sew. Treat. Works	
1880	3,077,871	671,831	0	21.8	0	0
1890	3,826,352	1,499,327	0	39.2	0	0
1900	4,821,550	2,480,785	21,877	51.5	0.45	0.88
1910	5,638,591	3,413,120	165,781	60.6	2.94	4.86
1920	6,485,280	4,481,602	424,706	69.2	6.55	9.48
1930	7,630,654	5,837,511	2,582,898	76.5	33.8	44.3
1940	7,897,241	6,065,726	5,461,756	76.8	69.2	90.2
1950	8,712,176	6,708,545	6,196,777	77.0	71.2	92.4

CHLORINE DEMAND OF WASTE FROM A CHEMICAL PLANT *

By Donald Tarvin

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The Calco Chemical Division of the American Cyanamid Company, at Bound Brook, N. J., manufactures dyes, sulfa drugs, chemicals used in the manufacture of rubber, and other organic chemicals. Inorganic and organic chemicals are used in the manufacture of these products. After recovery of by-products and treatment of some wastes at the source to remove color and oxygen consuming substances, the waste waters are pumped to the effluent plant. Reactions of chemicals occur in a compositing basin and the waste water is neutralized to pH 4.0 to 4.3 with lime and calcium carbonate. Precipitated materials are settled out as sludge in the compositing basin and settling lagoon, and the clear effluent is discharged to the Raritan River. This effluent contains some inorganic salts and low concentrations of organic wastes from the manufacture of organic chemicals.

It is the purpose of this paper to show that when the chlorine demand of this industrial waste was measured by the "Standard Methods," the results were inconsistent and the results using the starch-iodide method were much different from those obtained using the ortho-tolidine method.

Chlorine Demand by Starch-Iodide

Chlorine demand determinations were made daily on composite samples of Calco effluent from March, 1949, to July, 1950. Chlorine water was added to a series of portions of the sample using increments of 1 or 2 p.p.m. chlorine. After 15-min. contact, the residual chlorine was determined by the starch-iodide method according to "Standard Methods" (1, p. 148). Potassium iodide and starch were added to the sample and the liberated iodine was titrated with 0.01N sodium thiosulfate. The pH of the chlorinated samples was usually between 3.0 and 4.0.

The results of these determinations of chlorine demand ranged from 121.6 to 0.0 p.p.m. and averaged 21.1 p.p.m. for 17 months.

Effect of pH

Comparisons of chlorine demand of Calco effluent using the starch-iodide method for residual chlorine in neutral and in acid solution were made as follows. Several samples of effluent were neutralized to pH 6.2 to 6.7, and chlorine demand was determined using starch-iodide (a) without acetic acid and (b) with acetic acid added before the determination of residual chlorine. The results, summarized in Table I, show the chlorine demand (or amount of chlorine required to give a residual) with starch-iodide was about twice as much when the tests were made without acetic acid as when they were made with acetic added. The average demand was 85 p.p.m. without acetic and 40 p.p.m. with acetic.

To obtain additional information on effect of pH, the chlorine demand of a few samples was also determined using starch-iodide at the pH existing after

* Presented at 1952 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; March 12–14, 1952.

TABLE I.—Effect of pH on Chlorine Demand Using Starch-Iodide Method

pH		Acetic Added	Titration pH	Chlorine Demand (p.p.m.)		
Samples	After Cl_2			Max.	Min.	Av.
6.2–6.7	6.0–6.5	No	6.0–6.5	131.6	40	85
6.2–6.7	6.0–6.5	Yes	3.7–4.0	64.5	14.5	40

chlorination (pH 3.2 to 3.4) and after adjusting the pH of chlorinated samples to 4.0 and 7.0. The results, summarized in Table II, show that as the pH increased the amount of chlorine required to show a residual with starch-iodide increased.

The effect of lowering the pH was to lower the chlorine demand, as shown by Tables I and II. The amount of chlorine found was increased and the

TABLE II.—Effect of Titration pH on Chlorine Demand Using Starch-Iodide Method

Titration pH	Chlorine Demand (p.p.m.)
3.2–3.4	less than 10
4.0	19.3 to 39.7
7.0	100 to 160+

oxidation potential or oxidizing intensity of the effluent was also increased, as shown by Table III. Oxidation potentials were measured with a pH meter using platinum and calomel electrodes.

It is possible that the greater chlorine residuals found at lower pH may be explained by the presence of chloramines, or other nitrogen compounds. A series of determinations showed 30 to 32 p.p.m. ammonia nitrogen and 12.6 to 18.9 p.p.m. organic nitrogen in this effluent. It seems likely that when the pH is lowered, combined chlorine or oxidation products of chlorine and the effluent can release iodine from KI so that more residual chlorine is found at low pH.

TABLE III.—Effect of pH on Oxidation Potential

Sample No.	Chlorine Added (p.p.m.)	pH	Residual Chlorine (p.p.m.)	Potential (mv.)
1	115	5.4	0	+160
1	115	3.5	3.7	+325
2	12	3.4	0.07	+338
2	12	1.0	0.71	+445

Effect of Iron

Considerable iron is present in Calco effluent. Daily tests from May to September, 1951, generally showed 4 to 8 p.p.m. iron in the effluent discharged from the settling lagoon. When the chlorine demand test is made, chlorine will oxidize ferrous iron to ferric, according to the reaction:

$$Cl_2 + 2Fe^{++} \rightarrow 2Fe^{+++} + 2Cl^-$$

The ferric iron may in turn oxidize KI to iodine, which gives a blue color with starch.

$$2Fe^{+++} + 2I^- \rightarrow 2Fe^{++} + I_2$$

The resulting iodine may be attributed to the presence of chlorine, but is really released by ferric iron. To investigate the effect of pH, ferric chloride was added to distilled water, the pH was adjusted, and the starch-iodide test was made. The results (Table IV) indicate that below pH 4.0 ferric iron may oxidize KI to iodine, giving a false test for chlorine and the chlorine demand results will be too low.

If the pH of the chlorinated samples were adjusted to 4.0 before determination of residual chlorine, iron would not interfere. Accordingly, determinations of chlorine demand were made using starch-iodide for determination

TABLE IV.—Effect of pH and Iron on Starch-Iodide Results

Ferric Iron (p.p.m.)	Starch-Iodide Test			
	pH 3.0	pH 3.5	pH 4.0	pH 7.0
2	+	Trace	—	—
17	Strong +	Strong +	—	—

TABLE V

Conditions	Chlorine Demand (p.p.m.)		
	Max.	Min.	Av.
(a) pH after Cl_2, 3.3 to 3.9	19.8	5.8	12.2
(b) pH adjusted to 4.0	43.5	7.0	20.4

of residual chlorine (a) at the pH existing after chlorination and (b) with the pH of the chlorinated samples adjusted to 4.0. Results of 25 daily tests on samples from the settling lagoon outfall are summarized in Table V. The difference in the results under conditions (a) and (b) is attributed to the interference of iron below pH 4.0.

Ortho-Tolidine Compared with Starch-Iodide

During the early work on chlorine demand of Calco effluent, the ortho-tolidine method for determination of residual chlorine was tried. The use of color standards for residual chlorine was not found practical because of the interference of the color of the effluent with the color produced by ortho-tolidine and chlorine. More recent tests showed that the ortho-tolidine and chlorine color could be seen without too much interference by using a spot plate.

Comparative daily determinations of chlorine demand were made using the ortho-tolidine spot plate method and using starch-iodide with the pH adjusted to 4.0 to prevent interference from iron. The results for 29 days are summarized in Table VI. It will be seen that the chlorine demand as determined by the ortho-tolidine spot plate method was much higher than the demand as determined by the starch-iodide method. The average chlorine demand of 98 p.p.m. by the ortho-tolidine method was 4.7 times as much as the 20.9 p.p.m. by the starch-iodide method.

TABLE VI.—Comparison of Ortho-Tolidine and Starch-Iodide Results

Method	Chlorine Demand (p.p.m.)					
	Lagoon Inlet			Lagoon Outlet		
	Max.	Min.	Av.	Max.	Min.	Av.
Starch-iodide, pH 4.0	59.5	7.1	26.5	43.5	7.0	20.9
Ortho-tolidine	180	70	108	150	70	98

The results of additional determinations of chlorine demand using the ortho-tolidine spot plate method are given in Table VII. Tests were made daily on composite samples from the settling lagoon inlet and outlet. The average ortho-tolidine chlorine demand for five months for the settling lagoon outlet was 99 p.p.m. This compares with an average demand for 17 months of 21 p.p.m. by the starch-iodide method, as shown earlier. If these values for chlorine demand by the two methods are calculated to pounds of chlorine required to satisfy the demand of 20 m.g. (168,000,000 lb. of Calco effluent) per day, the results are 16,632 lb. of chlorine per day by the ortho-tolidine spot plate method and 3,528 lb. of chlorine per day by the starch-iodide method.

TABLE VII.—Chlorine Demands by Ortho-Tolidine Spot Plate Test

Month	Chlorine Demand (p.p.m.)					
	Lagoon Inlet			Lagoon Outlet		
	Max.	Min.	Av.	Max.	Min.	Av.
June	180	70	108	150	70	98
July	140	60	84	110	50	74
August	160	70	115	130	40	91
September	205	80	138	130	70	105
October	200	105	147	165	105	127
Average	—	—	118	—	—	99

Discussion

The lack of agreement between the results of chlorine demand determina-

tions made on this complex industrial waste appears to be caused by a difference in the ability of chlorinated compounds to oxidize starch-iodide, which changes with the pH of the waste, and to a difference in the sensitivity of starch-iodide and ortho-tolidine to oxidize compounds.

"Standard Methods" (1, p. 98) recognizes the fact that the starch-iodide titration carried out in acid solution yields higher values (for residual chlorine) than the neutral starch-iodide titration. Hallinan and Thompson (2), in a critical study of the thiosulfate titration of chlorine, showed that chlorine and chloramine gave higher titrations in acid solution than in neutral or slightly alkaline solution. Marks, Joiner, and Strandskov (3), and also Nusbaum and Meyerson (4), have pointed out that iodine released by chlorinated compounds in sewage reacts or is absorbed almost immediately in neutral solution, but this iodine persists in acid solution. All of the above facts tend to confirm the present results that chlorine demand determinations give lower results if the starch-iodide test is made in acid solution and higher results if made in neutral solution. As shown, very large discrepancies were obtained with Calco effluent.

Nusbaum and Meyerson (4) also reported results similar to those reported here. They show chlorine demand results using acid ortho-tolidine were the highest, those with neutral starch-iodide were next, and those with a modified acid starch-iodide were the lowest. However, the demand of Calco effluent is so much higher than the demand of sewage that the discrepancies in results are much larger than those obtained with sewage.

The determination of chlorine residuals with ortho-tolidine is subject to interference from the color of wastes and also from iron, manganese, and nitrites. Nusbaum and Meyerson (4) have referred to the work of Marks *et al.* (3)(5), stating that it is impossible to determine with any degree of exactness the chlorine residuals in sewage by the use of standard ortho-tolidine reagent because of slow reactions with chloramines, particularly organic chloramines.

It is suggested that the following explains why higher chlorine demands may be obtained with ortho-tolidine. A table of oxidation potentials published by Tarvin, Todd, and Buswell (6) shows an E_0 value of 0.873 v. for ortho-tolidine, as compared with 0.53 v. for the iodine-iodide system. This indicates iodide in acid solution can be oxidized by weaker oxidizing agents, which may fail to oxidize ortho-tolidine with production of color. Since the oxidation potential of ortho-tolidine is higher than the potential for iodide and iodine in acid solution, substances in sewage as waste must be oxidized to a higher degree to give a color or a residual with ortho-tolidine.

The studies reported in the literature on bacteria kill by subresidual chlorination, or chlorination with less than enough chlorine to give a residual with ortho-tolidine, and the development of sensitive methods for determination of residuals in sewage, such as the amperometric titration method and others (3)(4), are evidence of the need for more information than is given by present standard methods for determination of residual chlorine and chlorine demand of sewage. They are also attempts to determine whether chlorination to an ortho-tolidine end point is necessary.

Summary

1. Determinations of the chlorine demand of Calco effluent using the starch-iodide method for residual chlorine gave at least three different results for chlorine demand, depending upon whether the pH was below 4.0, at 4.0, or near neutral. The chlorine demand results increased as the pH increased. The starch-iodide method is subject

to interference from iron below pH 4.0 and may be subject to other interference.

2. Chlorine demand determinations using the ortho-tolidine spot plate method for determination of residual chlorine gave results which were more than four times as high as the demand using starch-iodide at pH 4.0.

3. The difference in chlorine demand results obtained by the starch-iodide and ortho-tolidine methods appears to be caused by differences in the strength of oxidizing agents in the effluent at various pH values and by differences in the sensitivity of starch-iodide and ortho-tolidine to chlorinated or oxidized compounds.

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DISCUSSION

By Thomas M. Riddick

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In the Summer of 1951 the writer was employed by the Calco Division of American Cyanamid Company to determine the chlorine demand of a representative sample of their treated trade wastes. This was for the purpose of ascertaining whether the divergent results then being obtained by their laboratory for methods A, B, and C would also be obtained by another analyst.

To gain some rough idea of the chlorine demand characteristics of this waste, a 1-l. sample was placed under constant agitation (employing a 500-r.p.m. mechanical stirrer), then titrated with a standardized chlorine water approximating 1.0 mg. chlorine per ml. Chlorine residuals were then determined with LaMotte sets having ranges from 0.0 to 1.0 and 1 to 10, respectively. Time increments of chlorine addition were approximately 3 min., as the potentiometer indicated this period necessary for completion of the reaction. The results are shown in Figure 1. The chlorine demand, as ascertained by deducting chlorine residuals from chlorine applied, shows a break at 40 p.p.m. of applied chlorine. One would judge, therefore, from this non-standard procedure that chlorine demand was in the neighborhood of 45 p.p.m.

On the following day tests were run in accordance with "Standard Methods" (1) procedure. Figure 2 shows residual chlorine as a function of chlorine applied. Here there is such a variety of results that one can only guess as to which method to select as being the most appropriate. According to the ortho-tolidine test the chlorine demand was 44 p.p.m., which by chance checks the previous non-standard method a great deal more closely than is capable of repetition. The chlorine demand according to the starch-iodide

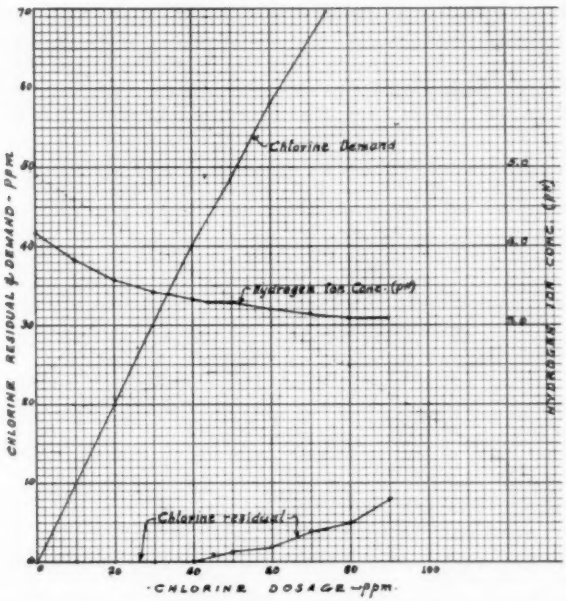

FIGURE 1.—Effects of adding chlorine water to 1 l. of Calco trade wastes, agitated continuously, with 3-min. time intervals between successive additions and using LaMotte standards in the ortho-tolidine test.

test, with or without acidification, was approximately 9 p.p.m.

If the sample is neutralized to a pH of 5.5 to 6.0 with sodium carbonate before the starch-iodide titration, the ortho-tolidine test gives a chlorine demand of 50 p.p.m. and the starch-iodide test 5 p.p.m.

Addition of calcium hypochlorite as a source of chlorine, instead of preparing a chlorine solution by breaking down calcium hypochlorite with acid

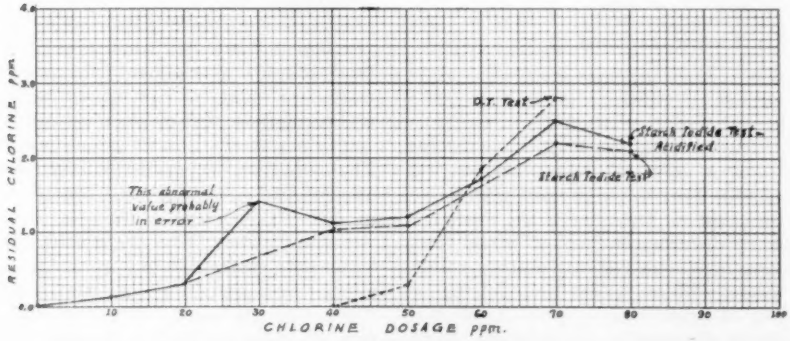

FIGURE 2.—Results of chlorine demand tests on Calco trade wastes using "Standard Methods" procedures.

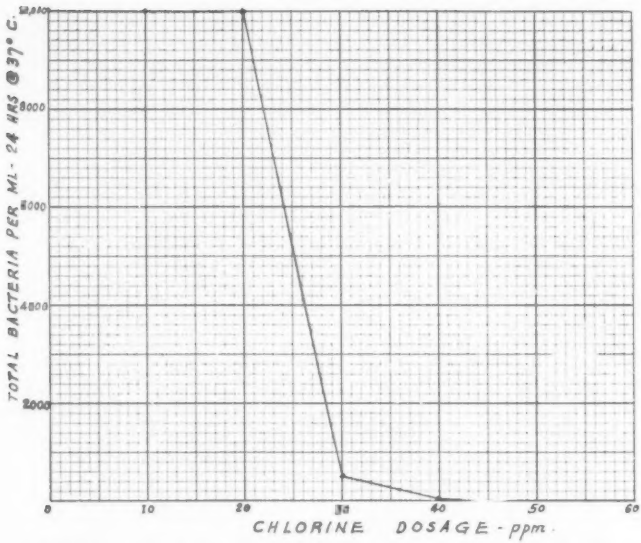

FIGURE 3.—Reduction of total bacterial count due to chlorination.

and bubbling it through distilled water, raised the pH from 4.2 to 5.0 and gave an indicated chlorine demand of 23 p.p.m.

These results may be summarized as follows:

Procedure	Std. or Non-Std.	Chlorine Demand (p.p.m.)
Ortho-tolidine test	N	45
Ortho-tolidine test	S	43
Ortho-tolidine test, second day	S	43
Starch-iodide, acidified	S	9
Starch-iodide, unacidified	S	9
Starch-iodide, unacidified, pH raised	S	5
Ortho-tolidine, pH raised	S	50
Hypochlorite added	N	23

These results can only be considered to be a mass of inconsistencies, the reasons for which are not readily ascertainable. The color of the waste was a reddish-purple, which would confuse most analysts attempting colorimetric differentiation and determination of interfering substances. Neither would distillation, precipitation, or filtration methods of clarification or color removal seem to greatly help this situation. There is little doubt that interfering substances (or confusing substances) were present. But whether they were sulfides or sulfites, nitrites or nitrates, unoxidized or oxidized forms of metals, reducing compounds of mineral or organic composition, or just plain organic matter, was a question outside the scope of the study.

Figure 3 shows a biological technique tried out by the writer. This is strictly preliminary and is not submitted as a panacea for the obvious ills of the chlorine demand test. Six bacterial colonies were selected at random from a nutrient agar plate of raw stream water and a small loopful of each was transferred to a sterile tube of lactose broth. The plate from which the colonies were selected had been incubated for 24 hr. at 37° C., hence the bacteria were young and fresh. The broth tube was vigorously agitated to break down clumps and distribute cells uniformly throughout the broth. After the addition of chlorine to the samples and after withdrawing specimens for standard tests, two drops of this bacterial

suspension were added to each beaker. The contents of the beakers were agitated and samples were withdrawn after 15-min. contact and transferred to nutrient agar. These plates were incubated for 24 and 48 hr. and total counts made. Results show the initial concentration of bacteria to have been approximately 10,000 or a saturated condition for nutrient agar plates. The waste sample containing 10 p.p.m. of chlorine showed no reduction, neither did the sample containing 20 p.p.m. The sample to which 30 p.p.m. of chlorine was added showed a decided drop in the die-away curve from 10,000 to 500, and the 40-p.p.m. sample contained only 1 or 2 bacteria per ml. Samples receiving dosages of 50, 60, and 70 p.p.m. of chlorine were sterile.

Although this biological work is extremely meager as well as rough, it seems to indicate that the chlorine demand, as determined by a kill of bacteria, was in excess of 20 p.p.m. but less than 40 p.p.m. It is probable that the dosage of 30 p.p.m., which lowered the total count from 10,000 to 500, must have resulted in a trace of chlorine or chloramine residual; and that the dosage of 40 p.p.m., which resulted in complete sterilization, must have created a chlorine residual probably in excess of 2 p.p.m.

The principal current reason for adding chlorine to sewages and trade wastes is to effect a destruction of coliform group organisms and to lower total counts from millions to, say, less than 100 per ml. It is believed, therefore, that further research along biological lines, using perhaps a standard strain of a readily identifiable bacteria (such as *Bacillus megatherium*) might result in a method which would produce results quite comparable with those obtained in plant operation. At worst it would add little confusion to the present dilemma in determining the chlorine demand of many trade wastes.

Reference

1. "Standard Methods for the Examination of Water and Sewage." 9th Edition. Amer. Pub. Health Assn., New York, N. Y. (1946).

STATUS REPORT ON SYNTHETIC RUBBER WASTES*

By Royal E. Rostenbach

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This progress report outlines many of the changes which have taken place since 1946 (1) in the treatment and disposal of industrial waste of the government synthetic rubber program.

During the period 1946–1948, 24 plants in the government synthetic rubber program were shut down, leased, or sold. The remaining plants operated at substantially reduced rates. Beginning in 1950 (2), and continuing on into 1951, 11 plants were returned to operation. Today, there are 13 copolymer (GR–S) plants, 2 Butyl (GR–I) plants, 10 butadiene plants, 1 styrene plant, 1 modifier plant, and 1 evaluation laboratory which are government-owned and operated in the synthetic rubber program. Table I lists the plants of the government synthetic rubber program according to location and presents the watersheds involved in their operations.

At the time the synthetic rubber plants were shut down plans were under way at some of the plants to improve the quality of the liquid wastes discharged. These plans were suspended immediately. Upon the reopening of the facilities the requirements for industrial waste treatment and disposal were reviewed immediately and plans were made for the necessary facilities to treat and dispose of the liquid wastes in a satisfactory manner.

An outstanding development of the synthetic rubber program in recent years has been the introduction of "cold rubber." The original production facilities were placed in operation in February, 1948. The production program has been expanded and during 1952, 75 per cent of the GR–S production capacity will be for "cold rubber." Another outstanding development has been the introduction of the oil-GR–S masterbatches. These new polymers were made first in April, 1951. The effects of these developments and new production on industrial wastes are taken up in another part of this report.

Throughout the years the managements of the plants have worked closely with the local, state, regional, and federal authorities. The quality of the liquid industrial wastes discharged has been reviewed periodically. In many cases improvement has been recommended as the result of joint studies by governmental representatives, plant operators, and consultants. Improvements made in the industrial waste program have been based on knowledge of the operators who are expert in synthetic rubber production, consultants specialized in the field of industrial wastes, and representatives of regulatory bodies informed on requirements and standards to be maintained.

As in any industrial operation, improvements in waste treatment and disposal can always be made. The position has been taken, however, that the modification of existing facilities and installation of new facilities must be economical. In each case the stream conditions have been evaluated and the expenditure of funds has been kept to a minimum. Many programs have been approved on a stepwise basis. The

* Presented at 26th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

TABLE I.—Plants of the U. S. Government Synthetic Rubber Program

Plant Location	Plant Operator	Type of Plant	Approx. Ann. Prod. Cap. (tons)	Watercourse at Site	Final Receiving Body of Water
Naugatuck, Conn.	U. S. Rubber Co.	GR-S	25,000[1]	Naugatuck River	Naugatuck River
		Modifier	1,800[2]	Naugatuck River	Naugatuck River
Akron, Ohio	Firestone Tire & Rubber Co.	GR-S	25,000[1]	Municipal sewerage and Ohio Canal	Little Cuyahoga River and Cuyahoga River
	Goodyear Synthetic Rubber Corp.	GR-S	23,000[1]	Municipal sewerage and Haley's Ditch	Little Cuyahoga River and Cuyahoga River
	University of Akron	Laboratory	—	Municipal sewerage and Ohio Canal	Little Cuyahoga River and Cuyahoga River
Kobuta, Pa.	Koppers Company, Inc.	Butadiene	105,000[2]	Ohio River	Ohio River
Institute, W. Va.	B. F. Goodrich Chemical Co.	GR-S	113,000[1]	Kanawha River	Ohio River
Louisville, Ky.	Kentucky Synthetic Rubber Corp.	GR-S	37,000[1]	Ohio River	Ohio River
	Union Carbide & Carbon Corp.	Butadiene	70,000[2]	Ohio River	Ohio River
Baton Rouge, La.	Copolymer Corp.	GR-S	43,000[1]	Monte Sano Bayou	Mississippi River
		Butadiene	22,000[2]	Monte Sano Bayou	Mississippi River
	Esso Standard Oil Co.	Butyl	40,000[1]	Monte Sano Bayou	Mississippi River
Lake Charles, La.	Firestone Tire & Rubber Co.	GR-S	86,000[1]	Bayou D'Inde	Calcasieu River
	Cities Service Refining Co.	Butadiene	62,000[2]	Bayou D'Inde and Calcasieu River	Calcasieu River
Port Neches, Tex.	U. S. Rubber Co.	GR-S	76,000[1]	Outfall canal and Neches River	Neches River
	B. F. Goodrich Chemical Co.	GR-S	78,000[1]	Outfall canal and Neches River	Neches River
	Neches Butane Products Co.	Butadiene	168,000[2]	Outfall canal	Neches River
Baytown, Tex.	General Tire & Rubber Co.	GR-S	37,000[1]	Scott Bay	San Jacinto River[3]
	Humble Oil & Refining Co.	Butyl	40,000[1]	Scott Bay	San Jacinto River[3]
		Butadiene	45,000[2]	Scott Bay	San Jacinto River[3]
Houston, Tex.	Goodyear Synthetic Rubber Corp.	GR-S	87,000[1]	Simms Bayou	Buffalo Bayou[3]
	Sinclair Rubber, Inc.	Butadiene	78,000[2]	Simms Bayou	Buffalo Bayou[3]
Borger, Tex.	Phillips Chemical Co.	GR-S	54,000[1]	Ditch and creek	Canadian River
		Butadiene	60,000[2]	Ditch and creek	Canadian River
Los Angeles, Calif.	Midland Rubber Corp.	GR-S	76,000[1]	Dominguez Channel	Los Angeles Harbor[4]
	Dow Chemical Co.	Styrene	57,000[2]	Dominguez Channel	Los Angeles Harbor[4]
	Shell Chemical Corp.	Butadiene	45,000[2,5]	Dominguez Channel	Los Angeles Harbor[4]
El Segundo, Calif.	Standard Oil Co. of Calif.	Butadiene		Pacific Ocean	Pacific Ocean

[1] Long tons. [2] Short tons. [3] Houston Ship Channel. [4] Pacific Ocean. [5] Combined capacity.

primary installations have been evaluated before proceeding with the secondary or final installations.

During the past years of operation many combined collection systems have been separated into industrial wastes, sanitary, and storm-water systems. Through this program the efficiency of the existing facilities has been increased. In other cases it has been possible to treat or dispose of wastes in a more satisfactory manner.

In the production of "cold rubber," the polymerization is carried on at approximately 41° F. The reaction at this temperature requires what is known as an "activated" recipe. All of the early recipes required the use of 2.5 to 3.0 parts of dextrose or glucose for each 100 parts of butadiene and styrene in the reactors. The use of sugar increased the oxidizable content of the liquid wastes discharged from the GR–S plants. The studies in research and development and production experience have led to the use of the so-called low-sugar and no-sugar recipes. The present sugar recipes require approximately 0.75 parts of sugar per 100 parts of monomers. In the near future it is anticipated that practically all of the production will be based on the no-sugar recipes.

Through the channel of research and development it was found that oil, known in rubber compounding as processing oil, could be added directly to the synthetic rubber latex, coagulated, and dried just as the normal GR–S production. The amount of oil has varied from 25 to 60 parts per 100 parts of GR–S. The final product, oil-GR–S masterbatch, has properties and utility of the magnitude of regular GR–S. The cost of the oil is very small, approximately 10 per cent of the cost of the GR–S.

For a number of years the carbon black masterbatches have been made. Now a sizable amount of production is made as oil-carbon black-GR–S masterbatch.

The addition of oil to the latex or the carbon black-latex slurry, followed by coagulation, results in the production of a solid masterbatch with no loss of oil to the industrial waste system.

Waste Control Practices

Houston, Tex.

The GR–S plant at Houston, Tex., is located on Simms Bayou, a tributary of Buffalo Bayou and the Houston Ship Channel. In 1949 the plant was modified to produce GR–S carbon black masterbatch (a product of approximately 100 parts of GR–S and 50 parts of carbon black). From experience at other plants it was recognized that some of the carbon black could escape and cause the waste waters of the plant to have a suspension of carbon black in them. Plans and appropriations were approved to provide for the coagulation of the waste waters from the plant. The final separator, which was of adequate size, was modified into two coagulation basins. To facilitate more efficient operation of this unit, the regional separators were modernized and improved. As a further improvement the storm-water system was separated from the other systems; hence the plant now has separate collection systems for industrial waste water, storm water, and sewage.

This plant also produces "cold rubber" and the oil masterbatches.

Baytown, Tex.

During 1950 a number of improvements and additions were made to the industrial waste collection and treatment at the butadiene and GR–I plants at Baytown, Tex. Cooling and storm waters were diverted from waste collection systems and certain other waste streams were diverted from the storm sewers. As a result, the efficiency of the existing regional and final separators was increased. At the GR–I plant an auxiliary separator was placed

in operation in the effluent improvement program. Scrapers on the inlet sections of the API separator were installed for the continuous removal of oil from the surface and sediment from the bottoms of these sections of the separator. Arrangements were made for the efficient collection and treatment of copper wastes from the butadiene plant. The boiler blowdown was neutralized so that the final waste water from the plants is the proper pH for discharge. The combined discharge of the liquid wastes of these two plants and an adjacent GR–S plant is to Scott Bay and hence into the Houston Ship Channel. Table II presents recent analytical data on the combined liquid wastes of the three plants: butadiene, GR–I, and GR–S.

TABLE II.—Liquid Wastes from Combined Operations of Three Plants: Butadiene, GR-I, and GR-S

pH	7.6
Oil (p.p.m.)	9
Susp. solids (p.p.m.)	79
B.O.D. (p.p.m.)	78
Diss. oxygen (p.p.m.)	2.0
Flow (g.p.m.)	2,000

In the production of butadiene, large quantities of waste water (known as quench water) are made. It is an emulsion of oil, condensed steam, and water. It is a difficult emulsion to break and passage through a gravity separator does not improve the quality appreciably. At the Baytown plant the emulsion is adjusted to about pH 4 to facilitate the separation of the oil and water. The emulsion is then passed through a filter to which a precoat has been applied. The water is used as a cooling-water make-up.

Institute, W. Va.

The GR–S plant at Institute, W. Va., was shut down in 1947 and reopened for operation in January, 1951. Many of the original industrial waste treatment units were reactivated immediately. Other units, recognized as inefficient, were placed in a temporary state of operation. Early in 1952 facility projects were authorized to improve the operation and efficiency of the existing units. Many small sumps are being abandoned. Waste streams having similar characteristics are being directed into the larger regional separators. The necessary construction work is under way and will be completed soon. As the result of all the work, critical areas of the plant will have regional separators or treatment units.

Louisville, Ky.

The GR–S plant at Louisville, Ky., was shut down in 1947 and reopened for operation in December, 1950. All of the existing treatment units were placed immediately in operation. It was recognized that improvement in the treatment of wastes was necessary. In 1951, a study of the existing facilities and plans for additions and modifications to the industrial waste treatment systems were completed. The plans include (a) the separation of storm-water, sewage, and industrial waste collection systems; (b) the treatment of sewage; (c) the modernization of regional separators; and (d) future provision for a final separator. Preliminary plans have been approved by the Kentucky Water Pollution Control Commission and detailed engineering work is now under way. The necessary appropriation by RFC will be required before construction starts.

Kobuta, Pa.

When the butadiene plant at Kobuta, Pa., was shut down, construction was under way for the erection of a distillation column and auxiliary facilities. This work was abandoned.

As soon as the plant was reopened for the production of butadiene from alcohol in November, 1950, one of the very first projects to be considered was a distillation system to handle the odoriferous wastes from the plant op-

erations. After a thorough review of the original plans and advancements made in treating wastes of this sort, new plans were formulated based primarily on the original system. Construction was authorized and the facilities placed in successful operation in October, 1951.

It was recognized that there would be a substantial improvement in the taste and odor properties of the waste discharged. The improvement in the oxygen demand as measured by conventional methods was not as pronounced. The taste and odor problem was the major problem to be solved at the time.

Los Angeles, Calif.

In the production of butadiene, one method of product purification is by the use of copper ammonium acetate. The copper solution is purified so that it may be re-used. The treatment and disposal of the waste copper solutions from this operation are industrial waste problems. At the Los Angeles butadiene plant the problem has been handled in a rather unusual manner. Through the cooperation of the Los Angeles County Sanitation Districts it has been possible to discharge waste copper solutions to the sanitary sewer, subject to quantity of copper and pH limitations.

Prior to the plant shutdown and immediately after its start-up in December, 1950, the following treatment and disposal were made of the waste copper solutions. The equipment consisted essentially of a chemical sewer system draining into the copper removal basin. In this basin the solution was adjusted to a pH of 2 to 4, agitation was achieved with compressed air, and the copper precipitated in metallic form by plating out on scrap iron. Fresh caustic was used sparingly for pH control. The treated solution was drained then into the combined effluent system and hence to the Knox Street treatment unit and into Dominguez Channel.

On receiving a permit from the county, facilities were installed to pump the untreated and dilute copper solutions into the sanitary sewer. This method of disposal was placed in operation in August, 1951. The new method has eliminated the need for sulfuric acid and scrap iron to plate out the copper, and caustic to raise the pH of the effluent.

It was essential to increase the pH of the Knox Street effluent. Prior to August, 1951, the average pH was 7.8. Since that date the average pH has been 8.6. The suspended solids content of the effluent due to ferric hydroxide was reduced significantly: the former average was 2.1 ml. per l.; the average since August, 1951, is 1.4 ml. per l. The discharge of approximately 3 p.p.m. of copper into Dominguez Channel, which was considered undesirable by various authorities, was eliminated.

Although the new method of disposal was developed primarily to improve the quality of the effluent, an economic benefit was realized. Savings in acid alone have averaged $1,300 per month. Operations were simplified to the extent that one-half of the operator's time now is spent on other duties. One job per shift was eliminated in the process, resulting in direct savings in the order of $1,500 per month. Savings in scrap steel and caustic were realized. In brief, an expenditure of $9,000 resulted in direct savings of more than $2,800 per month in addition to effecting major improvements in quality of effluent drained to Dominguez Channel.

The foregoing development is an excellent example of mutual benefits that may be realized when industrial personnel collaborate with pollution control authorities to solve a waste disposal problem. In this instance the

TABLE III.—Liquid Wastes from Combined Operations of Three Plants: Butadiene, Styrene, and GR-S

pH	8.6
Oil (p.p.m.)	18
Settl. solids (ml./l.)	1.4
Threshold odor	16
Flow (g.p.m.):	
Styrene plant	190
GR-S plant	735
Butadiene plant	1,120
Total	2,045

problem could not have been solved without complete cooperation.

At the styrene plant in Los Angeles a noticeable improvement was made in the separation of oil from the waste water containing aluminum salts. When aluminum hydroxide is precipitated in oily waste water, gravity separation is impaired. The problem was solved by installing an oil-skimming basin ahead of the coagulating basin. This makes it possible to remove oil quite successfully from an acidic waste water containing aluminum chloride in solution. The substantially oil-free effluent from the skimmer basin is made alkaline with waste caustic, and discharged into a settling basin. As the aluminum hydroxide precipitates, it removes the last traces of oil. The effluent from this basin is normally sparkling clear.

Table III presents recent analytical data on the combined liquid wastes discharged to Dominguez Channel, Los Angeles County, from three plants: butadiene, styrene, and GR–S.

Conclusion

Improvements have been made in many of the other plants not mentioned specifically. In all plants greater efforts have been directed to the operation of the industrial waste facilities to improve the operating efficiency of the units and the quality of the liquid wastes discharged.

Improvements have been made in the efficiency of operations. Collection systems have been separated. Modifications have been made to existing waste treatment and disposal facilities. New facilities have been added to improve the quality of the wastes discharged. Better methods of treatment and disposal have been developed, as outlined by specific examples. Some data on quality and quantity of liquid wastes have been presented. Cooperation with regulatory agencies continues.

Because of the present expanded synthetic rubber production, the industrial waste program has been increased greatly. The production of new types of rubber has given rise to new problems, which are being solved.

As in the past, considerable attention and finances have been directed to the treatment and disposal of synthetic rubber wastes from the government-owned plants.

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BIOCHEMICAL OXIDATION OF DAIRY WASTES

IV. Endogenous Respiration and Stability of Aerated Dairy Waste Sludge *

By Sam R. Hoover, Lenore Jasewicz, and Nandor Porges

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In previous work, the rate and extent of conversion of milk solids to bacterial cells by the mixed culture of microorganisms which becomes dominant during aeration of milk waste (1)(3)(4) was determined. Chemical equations for the synthesis of cell tissue were derived from these data. From these equations and separate determinations of the rate of respiration, the rate at which oxygen is taken from the solution was calculated to be 0.075 lb. of oxygen per pound of milk solids per hour per 500 p.p.m. bacterial cells (0.4 p.p.m. oxygen per minute) during the period of rapid growth of cells.

The further digestion of these cells by their own (endogenous) respiration has a definite practical importance. If this respiration proceeds at a great enough rate, the cells can oxidize their own tissue (autodigestion of sludge) rapidly enough to keep the system in balance; that is, no sludge will accumulate. If the autodigestion is not sufficient, sludge will accumulate and disposal is necessary. The rate of endogenous respiration is of further interest because of the proposed partial-treatment process described previously, in which the cells would be discharged to a stream daily (2). The consequent drain on the oxygen supply of the stream would be directly related to this rate of endogenous respiration.

The experimental techniques used have been described previously (1)(6)(7)(9). An active culture containing about 500 p.p.m. bacterial solids was maintained by continuous feeding of 1,000 p.p.m. of skim milk solids into an aeration tank. The detention time was 20 hr. The rate of respiration was measured in a Warburg manometric apparatus (1) or by evolution of carbon dioxide (8). The latter method was especially valuable for experiments continued for several days.

Experimental Results

The rate of oxidation of skim milk was determined by the two methods on the same sludge and compared with the rate of endogenous respiration (Table I). Measurements were made after 6 hr. and calculated on an hourly basis. Three facts of importance are shown by these data, as follows:

TABLE I.—Oxidation of Skim Milk Solids *vs.* Endogenous Respiration

Method of Determination	Endogenous Respiration	Oxidation of Skim Milk Solids
Manometric: O_2 cons. (ml./l./hr.)[1]	3.2	32.1
Titrimetric: CO_2 prod. (ml./l./hr.)[1]	3.9	30.3

[1] Data averaged over initial 6 hr.; 1.0 ml. O_2 = 1.43 mg.; 1.0 ml. CO_2 = 1.96 mg.

1. The oxidation of milk solids proceeds at a rate of approximately 10 times that of endogenous respiration.

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2. The respiratory quotient (R.Q. = vol. CO_2/vol. O_2) is approximately 1.0, in agreement with previous results and the theoretical equations for the two reactions that have been developed (1). Thus, throughout this paper, Q_{CO_2} can be considered to be equal to Q_{O_2}, for they are equal on a volume basis if R.Q. = 1.0.

3. The relatively simple titrimetric determination of CO_2 produced gives data for determination of the rate of respiration that can be considered equivalent to Warburg manometric data for the present purposes.

The previous determinations of rate of oxidation were run for 6 hr., which was the time required to complete the rapid assimilation of milk solids into the cells. Over this period, unfed cells in control experiments maintained almost a constant rate of endogenous respiration (1). It was necessary to determine the rate over a longer time if the autodigestion in an aeration system with a holding time of 30 to 40 hr. was to be calculated. The Q_{CO_2} (microliters of carbon dioxide per milligram of cells per hour) was measured for 48 hr. (Figure 1). The amount of cells present initially was found to be 410 p.p.m. Measured amounts of gas produced per milliliter were calculated to the milligram of solids basis necessary for determining the rate of oxidation on an absolute basis (that is, Q_{CO_2}) by use of the equations previously established (4). The rapid assimilation reaction was at a high and relatively constant rate for 4 hr. During the 5th and 6th hours it was completed, and the rate fell to that of the unfed sample. For the following 42 hr., the rate was almost identical with that of the unfed control sample. The initial Q_{CO_2} of the latter sample was 10.3; over a period of 48 hr. it fell only to 4. Q_{O_2} and Q_{CO_2} values of 8 to 12 for endogenous respiration have been obtained in a number of other experiments over a 6-hr. period. It is considered, therefore, that a Q_{O_2} of 10 is an average value for this rate.

The oxygen consumption in parts per million per hour was calculated from these experiments, for parts per million of oxygen is the common unit of measurement for dissolved oxygen

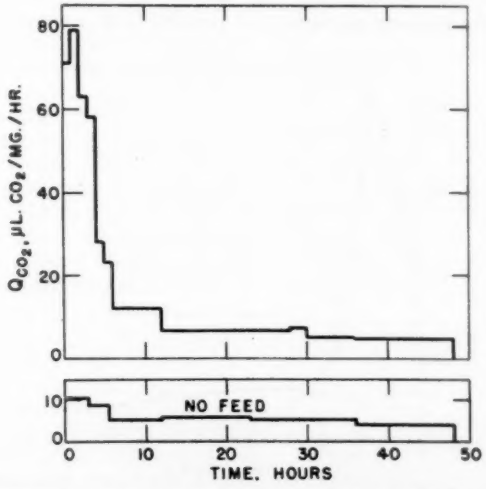

FIGURE 1.—Rate of removal of O_2 in oxidation of skim milk.

in sanitary engineering. The data in Figure 2 were obtained by direct manometric measurement of oxygen consumption. A maximum rate of 83 p.p.m. per hr. was obtained during the assimilation reaction. This value is much higher than that of 0.37 p.p.m. per min. or 22 p.p.m. per hr., which was determined by polarographic determination of oxygen removed (4). The greater rate may be due to the vigorous agitation of the culture in the manometric apparatus and the consequent lessened effect of diffusion through the liquid. Certainly, the rate measured in the present experiments can be considered comparable with the rate that would prevail in an aeration tank if oxygen were supplied fast enough. A second point of interest is the rate of oxygen uptake at the end of 18-hr. aeration, which was 7 p.p.m. per hr. It is readily seen that the air which should be supplied during the latter stages is much less than the maximum required for the first few hours.

These experiments were so designed that a convenient and accurate determination of the rate of oxidation could be made. They did not simulate the proposed partial-treatment process, for the final sludge was about twice as high in total solids as would be maintained by a fill-and-draw operation. An experiment was set up, therefore, in which 400 ml. of simulated waste (1,000 p.p.m. skim milk solids) were added to 100 ml. of active sludge that contained 380 p.p.m. solids. The rate of oxidation was determined by evolution of CO_2 and calculated to O_2 consumption per liter of mixed liquor (Figure 3). The addition of 4 volumes of a strong waste to 1 volume of a dilute sludge did not result in as high a rate of oxidation as was observed in the previous experiments, for there were not enough organisms to produce a maximum rate when the data are calculated on a volume basis. If the results were plotted as Q_{O_2}, the data would be comparable with those of Figure 2; the activity of the cells is high on a dry-weight basis.

The cumulative curve plotted against the ordinate on the right side of Figure 3 is significant, for it is in agreement with the theoretical analysis of the reactions published previously (4). The simulated waste, 400 ml. of a solution containing 1,000 p.p.m. skim milk solids, contained 400×0.88 (correction for ash and moisture), or 352

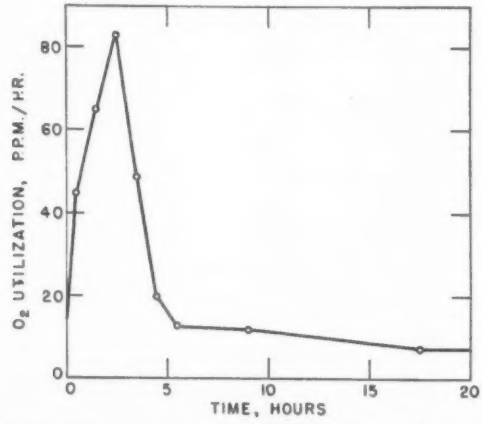

FIGURE 2.—Rate of aerobic oxidation of 1,000 p.p.m. skim milk solids.

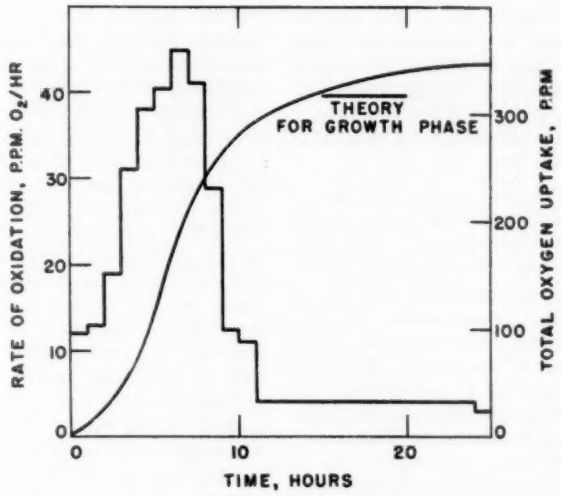

FIGURE 3.—Oxidation of 800 p.p.m. skim milk solids.

p.p.m. protein and lactose. According to the equations previously derived, the assimilation of this amount of skim milk would require 352:424::x:192, $x = 159$ mg. O_2 per 500 ml., or 318 p.p.m. O_2. The rate of oxidation fell from that characteristic of the assimilation reaction to that of endogenous respiration when the cumulative oxygen consumption totaled 300 p.p.m., in excellent agreement with the value calculated from the earlier manometric experiments.

The absolute rate of the endogenous respiration for the whole 11- to 23-hr. period was 4 p.p.m. O_2 per hr.; for the final hour the rate was 3 p.p.m. O_2 per hr. Analysis for organisms present after 24 hr. showed there were 570 p.p.m. organic solids, yet the rate of oxidation was only 3 p.p.m. O_2 per hr. This low rate proves that the oxygen drain on a stream would be rather low and further justifies the proposal that a fill-and-draw aeration, with discharge of the whole effluent from the aerator would be an inexpensive and effective treatment for milk wastes (2)(5).

Discussion

The composition of the sludge organisms was established previously, and the following equation of endogenous respiration was derived (4):

$$C_5H_7NO_2 + 5\ O_2 \rightarrow 5\ CO_2 + NH_3 + 2\ H_2O$$
$$113 + 160 \rightarrow 220 + 17 + 36$$

The empirical formula $C_5H_7NO_2$ accounts for the organic constituents of the sludge. It has a formula weight of 113. The oxidation of one mole then requires 160 atomic weight units of O_2 and produces 220 units of CO_2. By use of these values and the following constants, the relative rate at which cells are consumed by their endogenous respiration can be calculated:

22.4 l. O_2 = 32 g. O_2

1 μl. O_2 = 1.43 μg. O_2

Q_{O_2} = μl. O_2 per mg. cells per hr.

A Q_{O_2} of 10 = 14.3 μg. O_2 per mg. cell tissue per hr.

According to the equation, 14.3 μg. $\times \frac{113}{160}$ = 10.2 μg. cell tissue oxidized

per hr. by 1 mg. of cells. But, 10.2 μg. = 0.0102 mg., or 1 per cent per hour. Therefore, a Q_{O_2} of 10 = 1 per cent of cell tissue oxidized endogenously each hour; a Q_{O_2} of 5 = 0.5 per cent, etc.

These calculations can be applied in practice as follows:

Assume that one volume per day of a waste containing 1,000 p.p.m. solids (640 p.p.m. 5-day B.O.D.) enters the treatment plant. The assimilation reaction will produce 500 p.p.m. of sludge. If a concentration of 2,500 p.p.m. of sludge, which has a Q_{O_2} of 10, is maintained in the system, 25 p.p.m. would be consumed by endogenous respiration hourly, or 500 p.p.m. in 20 hr. Such a system would be in balance and sludge would not accumulate.

The performance of an aeration system could be evaluated by the following determinations:

1. Chemical oxygen consumed and volume of waste entering.
2. Sludge solids (by oxygen consumed or direct determination).
3. Q_{CO_2} of sludge fed a simulated or actual waste.
4. Q_{CO_2} of unfed sludge.

Calculation of the solids balance from these measurements would give the performance of the treatment plant. For example, the oft-repeated statement that "this plant does not produce any sludge" could be checked. If the results showed an oxidative capacity appreciably lower than that required for complete oxidation, a reasonable possibility of occasional loss of sludge solids in the effluent would exist. If the rate was sufficient to keep the system balanced, the design and operation of the plant would be verified.

The data presented should also be evaluated on another basis. The primary purpose of plant waste treatment is to reduce the drain on the oxygen of the stream into which the effluent flows. According to the accepted standard of oxygen demand, the 5-day B.O.D., the fill-and-draw process reduces the pollution 75 to 80 per cent (2). The results (Figure 3) show that the endogenous respiration of the cells in the effluent which would be discharged to the stream is only 3 p.p.m. O_2 per hr. This rate is far lower than a comparison of the B.O.D. of the raw and treated waste would indicate. The raw waste has a maximum rate of oxidation of 40 to 45 p.p.m. O_2 per hr., and the treated waste less than 4 p.p.m. per hr., or a reduction of more than 90 per cent. It is probable that the greater reduction indicated by the rate of respiration is a more valid indication of the decrease in pollution than is given by the standard test. Carefully planned field experiments will be required to establish the validity of these latter ideas.

Summary

The rate of endogenous respiration (aerobic autodigestion) of the mixed culture of organisms that oxidizes dairy waste aerobically has been determined. The rate is low; the sludge produced by the oxidation of 1,000 p.p.m. skim milk solids consumes 3 to 4 p.p.m. O_2 per hr.

The same culture in the active-growth phase consumes oxygen at a rate of 40 to 45 p.p.m. O_2 per hr. The 10-fold difference between these rates is an important factor in the operation of existing plants and in the design of new plants.

The reduction in rate of oxidation brought about by conversion of milk solids to bacterial cells is much greater than the reduction in B.O.D. The theoretical and practical consequences of these differences are discussed.

Acknowledgment

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HOW TO MAKE INDUSTRIAL WASTE SURVEYS

"Planning and Making Industrial Wastes Surveys," a recent manual by the Ohio River Valley Water Sanitation Commission, is a "how-to-do-it" description prepared for the use of operating men whose normal duties may be quite remote from the conduct of a waste survey but who, nevertheless, may be called on to do the actual job.

Developed by the Commission's Metal-Finishing Industry Action Committee, the manual is not limited to the problems of that industry but covers the basic requirements of solving all types of liquid industrial wastes problems.

Included in the manual are detailed instructions and illustrations for planning the waste survey, measuring the flows, taking samples, and calculating the waste loads. Illustrations of sampling devices and methods, together with pertinent hydraulic tables for pipe flows, weir flows, and Parshall flumes, make the procedure outlines easy to follow.

Copies of the 46-page manual are available at $1.00 per copy from the Ohio River Valley Water Sanitation Commission, 414 Walnut St., Cincinnati 2, Ohio.

Stream Pollution

SOME ASPECTS OF POLLUTION CONTROL IN TIDAL WATERS*

By Kerry E. Mills

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The volume of available literature on the industrial pollution problem is rapidly exceeding the budgeted reading time of the industrial personnel who are assigned to the job of pollution control. It has been reported by Rudolfs and his associates that as recently as 1949 general reviews of the subject covered 398 references, whereas the number had swollen to 661 in 1950 and to 767 in 1951. The publications cover every imaginable phase of the problem: analytical methods, sewage treatment, legislative activity, bio-assay testing, biological survey methods, radioactive wastes, paper mill wastes, the administration of stream pollution prevention, and a score of other topics.

Many, if not most, of the industrial technologists concerned with pollution control find themselves in a new and strange field. With training in chemistry or chemical engineering, their background contains little or nothing concerning sewage treatment, biological oxidation of phenols, or any of the esoteric skills possessed by bacteriologists and biologists. It is certainly true that these subjects are now being included in many sanitary engineering curricula, or others related to pollution control, but industry, to a great extent, has already been compelled to start the job with members of its present staffs.

From the mountain of assorted literature on pollution problems, the refinery technologist has learned to pick out articles on oil removal, caustic stripping, and other specific information that obviously fits his problems. Likewise, the chemist or engineer at a chemicals plant can, for example, focus on available results with biological treatment methods as applied to materials similar to his. These expedients are valuable as far as they go, but what is the direction of the total effort?

Over-All Objectives

In asking this question the emphasis is at once removed from the multitude of definite technical problems concerning pollution—problems that are particular not only to each industry, but even to each plant—and placed on the philosophy of pollution abatement and control. It should be explained that in this case by philosophy is meant the objectives, or set of values, in accordance with which the industrial waste disposal problem is designed or directed. Without establishing a definite over-all perspective, the industrial program tends to be spotty, confusing, slow to develop, and needlessly expensive. To be more specific, the need for a set of objectives, or philosophy, can best be exemplified by posing several questions. Is the waste water discharged from a plant bad or is it satisfactory? Why is it good or bad? After certain cleanup treatments have been applied, is the water now suitable for discharge to streams or tidal waters? Is it indicated that nothing

* Presented at 1952 Texas Water and Sewage Short School; College Station, Tex.; March 9–13, 1952.

worse than pure water be discharged, or will somewhat lower quality be acceptable? The first reaction to these inquiries is one that has created continuing disagreement; namely, establish a set of standards. This attitude is an over-simplification of the problem. What qualities of the water should be standardized? How are the standard limits scientifically determined? Should there be one set of standards for each industrial plant, one set for each river and estuary, or one set for each state? The industrialist is vitally interested in the ultimate baselines chosen, because he is the one on whom the burden of conformity is placed. It is readily apparent in examining the efforts of control commissions and agencies in certain states, that arbitrary decisions on these factors have already been made, with subsequent insurmountable difficulties in regard to their utility and desired function.

There is no easy answer to a situation as complex as that of stream and tidal water pollution. For this reason, it is obviously a product of good judgment for everyone concerned to avoid precipitous innovations and indefensible conclusions.

How does this sort of thinking about objectives, and the clear approach to a pollution control program, apply to the effect of refinery wastes in salt water? Basically, the problem is the same as it is for fresh-water streams or lakes; the differences are parallel rather than actual. That is, on one case there are species of fresh-water fish, crustaceans, plankton, and bacteria; in tidal waters these life forms are still there, even though the types and relative distributions of species are different. River water is often used for municipal drinking supplies; salt water, on the other hand, is generally preferred for bathing. And yet, how can one enjoy bathing without swallowing appreciable volumes of the water? Rivers flow past the site of industrial plants and carry the wastes away—or on to the next fellow downstream. Tidal action incrementally removes wastes, and where several industries are situated on the same coast, littoral currents and rip tides may bring the wastes from one plant into the outfall region of another plant.

Actual Stream Condition Should Govern

In all these cases, tidal as well as stream, the consideration that should receive first attention has been concisely expressed by Doudoroff (1), in the question: "In what practical sense is the condition of the affected stream less satisfactory than it was before?" The implication is that involved studies of all the living forms present in the water, together with their seasonal and locational variations, may lead the industrial technologist into expensive and academic channels of investigation without the results bearing directly on the pollution problem. What is needed is the detection, reliable estimation, and understanding of the effects of pollutants on aquatic resources of economic and recreational importance. Consideration of pollutional effects and their remedy from the point of view of the practical function of the receiving watercourse appears to be a reasonable and workable premise. Why should a specific material be removed from an industrial effluent, down to say 1 p.p.m., if no practical difference in the normal function of the receiving body of water can be demonstrated if 3 p.p.m. are present? Conversely, why instigate expensive and time-consuming studies for the removal of nitrate ion, when the watercourse is being impaired not by nitrate ion in the concentration expelled, but by even lower concentrations of cupric ion?

If the industrial pollution engineer is to be guided by this premise of practicality, it seems indicative that he must immediately devote his attention to the problem of the biological and bacteriological balance in the re-

ceiving water. This, however, is only one of the many phases of the problem with which he has to cope. What are these additional problems, and more important, in what sort of logical order should they be considered?

With regard to both in-plant efforts and an understanding of stream conditions, there are the problems of sampling, analysis, flow rates, volumes, and physical layout. In addition to these, treatment method studies apply in the plant, and the effects of the waste discharge on the receiving body of water outside of the plant. Waste treatment methods accepted without regard for stream effects can easily prove calamitous if later conditions in the watercourse show the need for additional more rigorous cleanup. This can lead to unnecessary expenditures for a second treatment plant where a different one would have done the job in the first place or the existing treatment plant may be rendered entirely obsolete.

Biodynamic Requirements

Although sampling, analysis, and other phases of the industrial pollution problem are complicated by deficiencies and lack of reliable techniques, it is not the purpose of this paper to discuss these particular problems. Because the pollutional effects in the watercourse are directly related to biological phenomena, and because, in turn, it is the biodynamic requirements that ultimately dictate permissible quality of and, therefore, treatment of the industrial discharge, it is to this aspect of the problem that attention is given.

It is evident that inferences of stream conditions from chemical and physical data are hazardous. Chemical tests, for example, tell nothing about toxicity. It is not obvious, however, that a knowledge of all or numerous of the life types present in a stream is any more valuable than an extensive chemical analysis. It is stated that biological studies reveal the true effects, particularly on a long-term basis, whereas chemical data only point to causes under present conditions; and yet, there seems to be a longing for someone to establish safe concentrations for every molecular species so that biological testing will no longer be necessary. Inasmuch as the action of chemicals, from a pollution standpoint, is different for different types of water, such a list is impossible. In addition, chemical agents acting together may demonstrate synergy or antagonism and thus invalidate individual evaluations.

Oceanographic Factors

Any particular natural water environment is a combination of factors. Physically, the bottom gradient and condition and the drainage can best be determined by oceanographic methods. Chemically, such qualities as dissolved oxygen, pH, suspended matter, etc., can be determined analytically. Biologically, the characteristic plant and animal life under natural balance may be verified by marine population studies. These latter studies reveal natural equilibria which, under polluted conditions, are changed to some other set of conditions. Heavy organic pollution, for example, acting as food for certain species of bacteria, results in tremendous expansion of these bacterial populations and concomitant depletion of the oxygen supply. With this condition prevailing, out go the fish and other larger forms. In gaining an understanding of biological conditions, an effort should be made to eliminate all unnecessary steps by a direct approach. If the damage to the watercourse concerns human health (that is, sewage contamination), then bacteriological evidence is sufficient and there is no need for capturing, identifying, or culturing 10 different varieties of plankton.

The pursuit of field bio-studies in tidal waters requires a knowledge of

tidal characteristics, bottom configuration, water quality, and some of the surface, pelagic, and benthonic life forms. In coastal areas, where there is a marked steep descent toward great depths, running from the line of constant immersion to a depth of about 360 ft., the continental shelf and slope structure is evident. This type of bottom will be associated with particular tidal behavior and likewise, in the case of pollution, certain purification or waste removal rates. On the other hand, in estuaries and bays similar, for example, to Galveston Bay, the water is of generally uniform depth throughout the entire body of water. In such enclosed regions the action of littoral currents and tidal cycles is at a minimum. The same types of fish and other marine life are distributed over the entire area and concentrations of shellfish forms can be found on scattered banks and shoals. Great variations in the tidal prism occur, ranging, in the case of Galveston Bay, from 75,000 acre-ft. with small declination tides to 1,250,000 acre-ft. during strong northers, and several million acre-feet in a hurricane period. Dike and dock structures do not, of course, restrict the action of the tidal prism, but turbulence occasioned by wave action, and the scouring of bottom solids, is decreased. The water mass shuttles back and forth with a regurgitative action that offers the poorest opportunity for dilution, renewal, and the elimination of horizontal and vertical stratification. This stratification, which occurs in the regions where waste-water outfalls enter the Bay, is further aggravated by the lack of climatic variations, which, through cooling, ice formation, or periodic large temperature changes, tend to equalize density differences.

Although geodetic survey data for a local tidal area will yield adequate information concerning bottom and shoreline configuration, as well as gross tidal action, changes in the water at the waste discharge point must be determined by individual investigation. Calculations of convergent geometrical series for prediction of the dilution or turn-over rate are based on the proportion of the total waste removed by one tidal cycle. This is all very well if antibiotics or natural antagonisms do not exist in the watercourse; but they usually do. A more reliable measure consists in salinity-temperature-density measurements taken with available indicator equipment or by hand sampling at several depths. Not only will these measurements indicate the rate of diffusion into the tidal prism, but they will also yield more reliable data on flow patterns than those obtained by the customary float studies. An additional advantage of the direct sampling technique is gained by having the samples available for further chemical and biological examinations. In this connection, it should be mentioned that composite samples over 8 hr., 24 hr., or longer periods of time are excellent for engineering purposes, but dangerous from a biological standpoint. Pollutional shock loads of only 1- or 2-hr. duration can damage the receiving body for weeks or months. Such effects are totally obscured by the average concentrations that are an inherent property of composite samples.

Flow and dilutional data obtained by all these physical observations are adequate for determining the course and fate of the waste discharge; the effects of the waste, however, must not be inferred from this kind of evidence. In some cases serial dissolved oxygen determinations have been obtained in the polluted area. These studies only demonstrate whether the pollution is gross or mild, and the approximate area involved; they do not designate causes or secondary effects. To illustrate, if the waste discharge contains oxidizable colloidal matter that is precipitated by the salinity of sea water, this material, by accumulation on the

bottom, will set up an anaerobic condition. The products of this bacterial benthic decomposition tend to diffuse upward into the water mass. Consequently, further oxidation to nitrate, carbon dioxide, and water deplete the oxygen supply in the water; this action is not revealed by periodic determinations of dissolved oxygen in the water.

Biological Factors

These considerations now lead into a brief survey of so-called field or biological studies as the next logical step in a plan that starts with the oceanographic evidence. Field studies should be concerned with two major factors—food and oxygen. Because many life forms feed on each other, particular emphasis is placed on the oxygen supply. With regard to toxicity, as compared with the oxygen balance, it is often found that toxic pollutants indiscriminately kill off most of the smaller marine biota and many of the fish species. An oxygen deficiency, on the other hand, is selective, acting, in this respect, in a similar manner to inert solid material. In the same connection it is unfortunate, but true, that the rate of oxygen depletion is higher in sea water than it is in other waters, resulting in a higher incidence of anaerobic activity. At this point it is helpful to recall an earlier statement that the purpose of field studies is not directed at an understanding of food conditions or the oxygen balance *per se*, but only insofar as these elements lead to an understanding of the practical, the economic, or recreational damage, if any, caused by the waste discharge. In the absence of irritating or noxious constituents the average bather, for example, is not usually occupied with the food value of diatoms. Nor does the water feel any better when it contains 8 p.p.m. of oxygen as compared to 4 p.p.m.

The selective action of variations in the dissolved oxygen content are apparent in sea water as well as in fresh water, but the choice of index organisms is dependent on the natural biota of the particular watercourse. In some cases, for example, this selectivity has been generalized by ascribing recently polluted, septic, and recovery to the progressive water zones downstream from a waste outfall. In the same order, in these zones, can be found aqueous fungi, rat-tail maggots, and bloodworms. Such a classification reveals flow conditions, dilutional effects, and purification in areas of gross pollution, but is not informative concerning practical conditions in the recovery zone or in areas of original mild pollution.

Biological field studies, bio-assay tests, in-plant waste studies, and waste treatment plant installations should all be directed toward the same objective—alleviation of those conditions that destroy or detract from the practical utility of the receiving body. It is conceivable that situations can prevail where waste disposal control in tidal waters need only be concerned with damage to the hulls of ships. In such limited areas where recreational or fishing activities are not warranted, how can elaborate waste treatment be justified? In most cases, however, the bathing or fishing facilities of coastal waters are considered valuable. The two functions have essentially the same requirements, absence of toxic and irritating materials in concentrations high enough to be injurious to humans or marine life. Sewage treatment, as a special requirement for beaches, can apply equally well to fishing areas, not only because of oxygen depletion, but also because of the possible contamination of the fish with pathogens.

Fish As Index

It is evident, therefore, that an approach to biological field studies is well taken if fish life is chosen as the major index of effect. Emphasis is

sometimes placed on dynamic equilibrium. This equilibrium, it is explained, should be determined by a corps of aquatic biologists, bacteriologists, botanists, and whoever else is necessary. How is such a course of much value when natural habitats are normally unstable? As a matter of fact, with chronic pollution, conditions may be more stable. A complete understanding of all marine life, with fish life just thrown in as another phase, is singularly academic and impractical. There are, of course, special conditions when pollution can affect the water in undesirable ways without any appreciable damage to the fish. In these instances, taste, odor, or irrigational difficulties can arise. In general, there are some relationships between fish populations and the type and abundance of plants and invertebrate animals, but there is no evidence that the variety of organisms present is always a good index of fish production.

Emphasis belongs on fish population. Creel studies and fish capture with nets afford a short-term means of determining what is going on. The fish are studied for habits, size, relative value, physical condition, and rate of growth. The appraisal must distinguish between transient and nonmigratory forms, as well as crowded areas adjacent to sparsely populated areas between which the fish migrate in relation to the severity of pollution. If the water is normally inhabited by trout and redfish, the presence of carp and mullet is just as indicative of pollution as if the area were devoid of fish. If the desirable species are top feeders, some knowledge of plankton conditions is useful, to the exclusion of most other life forms; with bottom feeders (for example, catfish) bottom sampling and study is indicated. In some cases, the fish feed on bottom organisms that are surface feeders, or on zooplankton that are in turn plant feeders. What these several phenomena actually signify is that the fish population itself is the index or pointer to the other smaller forms that need to be considered. In this way, a tremendous amount of effort can be saved when compared to a complete biological survey. Some knowledge of influences that do not apply directly to fish activity may, however, come in handy. Unusual quantities of plankton, for example, may indicate a drift from other areas, as this material is migratory. It may, on the other hand, be an indicator of organic pollution.

To determine the causes of the effects observed in the field studies, are the functions of chemical analyses and bioassays. Oftentimes the results of toxicity tests or bio-assays will give a clue to the kind of pollutant present. This can then be corroborated by direct chemical testing for the suspected material. Although the development of proper bio-assay techniques for pollution control is still a current problem, the groundwork has been well enough established for the industrial technologist to begin work in this field. As an example of progress in the methodology of toxicity testing, recent research at the Academy of Natural Sciences in Philadelphia is worthy of mention. That portion of these studies related to salt-water pollution included two species of diatoms, which are the algal forms that constitute food for oysters and other invertebrates; the sand, glass, and brine shrimp forms; two sea anemones, chosen for their sensitivity to changes in water quality; and one fish form, the killifish. The organisms were studied in laboratory aquaria under controlled conditions of aeration, temperature, light, and feeding. Organisms of comparable size and health were exposed to polluted water of known concentration, and observations of tolerance limits were made by recording the number of organisms still living, general activity, response to feeding, and response to tactile stimuli. This sort of testing procedure, or vari-

ations of it, represents a valuable tool for determining damage due to toxicity, and which fractions of industrial wastes contribute to this toxicity. Safe rates of discharge to the receiving water either before or after treatment are also obtainable from these assay studies. The results, in any case, are a reflection of toxic conditions rather than oxygen deficiencies.

In the application of bio-assay techniques to oil refinery waste water, predictions of most contaminants that are suspect can be deduced from prior knowledge of petroleum composition and process products. Chemical analyses for these substances will afford approximate measures of loading, not only in the final waste discharge, but in the contributory primary streams. The following basic classification of available test methods points out the relationship of the quality measured to the total pollution picture:

1. Oil determinations are primarily directed toward surface abnormalities caused by hydrocarbon films and films produced by other neutral or basic insoluble organics.

2. In the water mass, ammonia, nitrogen bases (chiefly pyridine), sulfides, mercaptans, phenols, and heavy metals contribute to general toxicity. As a special case, the phenols may be present in concentrations too low to have a demonstrably deleterious effect on marine life, and yet contribute an offensive taste to fish or a disagreeable odor to the water.

3. All the mentioned substances, as well as sanitary sewage, compose the elements comprising the total oxygen demand or B.O.D. Organic acidity, as distinct from mineral acid content, also falls into this class.

4. Oxygen consumed values and chlorine demands are of indirect value only if a reliable correlation exists between them and the B.O.D.

5. pH is the best index of excesses in mineral acidity or alkalinity.

6. A series of tests measures the components that affect salinity. It is understood, however, that salinity, which is a serious consideration in fresh water, is relatively unimportant in sea water. It can become important, however, if field studies reveal the presence of fish whose major items of food are forms of stenohaline crustaceans or other organisms highly susceptible to changes in osmotic pressure. These tests are for total dissolved solids, phenolphthalein alkalinity, methyl orange alkalinity, chloride, sulfate, calcium, magnesium, and soluble silica.

7. Measurements of total suspended matter, and supplementary identification of its composition, are directed toward those materials that precipitate as decomposable benthal sludges or inorganic blankets. Before precipitation in the euphotic or sunlit zones of shallow water, these suspensions can also cause light starvation to both pelagic and bottom plant forms. Similarly to B.O.D. and oxygen consumed, a correlation often exists between total suspended matter and turbidity. This permits substitution of simple turbidity readings for the tedious gravimetric solids analyses.

8. Tests for color and odor may be run, although the causative agents are usually included in other more exact measurements of specific contaminants.

Program Outlines

These major phases of industrial water pollution abatement can be combined into a program that directs the progress of understanding and control in some sort of logical sequence. For the sake of brevity, the points are presented in outline form, as follows:

I. General inspection.

A. Examine the receiving body of water in the area of the waste outfall for a septic condition, strong odor, high turbidity, strong color, or heavy oil contamination.

B. Determine from plant practice if raw sewage or large amounts of toxic materials are entering the outfall.

Gross Pollution

The prevalence of either condition A or B is indicative of gross pollution. If this is the case there is no immediate need for field studies or bio-assay testing and the program may be developed in the following manner:

1.—Detailed in-plant study of all primary waste sources to include sampling, analysis, flow rates, volumes, and physical layout.

2.—Guided by the data obtained in step 1, modify or change processes, where feasible, to stop the discharge of oxygen-consuming or known toxic wastes.

3.—From prior practice or bench and pilot-scale studies, determine suitable treatment for the major discharges contributing to oxygen demand or toxicity loads. Make allowance in design considerations for additional streams or the later adoption of secondary treatment.

4.—Install the plant-scale facilities determined by the results of the studies in step 3.

5.—Following a suitable period for recovery in the receiving body, instigate an oceanographic and biological field study to determine the effect of the improved quality waste stream on the watercourse. Make allowance in this study for the persistence of accumulated bottom sludge decomposition.

a.—If the field study reveals that conditions in the receiving water are satisfactory for continued discharge, with regard for practical considerations of the water function, establish proper treatment control procedures to maintain these conditions. Introduce no new processes or changes that might result in a decrease of total effluent quality.

b.—If the field study reveals that the waste stream is not satisfactory, determine additional treatment necessary by addition of more in-plant waste streams to the existent facilities or secondary treatment installation. These new facilities are directed by the results obtained from bench-scale bio-assay tests with those organisms found by the field survey to be important in relation to the economic or recreational function of the receiving water. These tests are designed to determine the tolerance limits of the individual and mixed pollutants identified by the in-plant survey.

b (1).—From prior practice or bench and pilot-scale studies determine suitable secondary treatment for the offending streams.

b (2).—Install the plant-scale secondary treatment facilities.

b (3).—Repeat the field survey in step 5 and continue in the direction indicated by the results.

Moderate Pollution

If the observations made during the general inspection reveal moderate instead of gross pollution, the initial steps in the program are modified as follows:

1. *a*.—Detailed in-plant study of all primary waste sources to include sampling, analysis, flow rates, volumes, and physical layout.

b.—Simultaneously with the in-plant study, evaluate the condition of the receiving water by an oceanographic and biological field study.

2.—Run bio-assay tests to determine tolerance limits.

a.—Test those pollutants found by the in-plant survey.

b.—Use the same or related organisms found by the field survey to be important in relation to the economic or recreational function of the receiving water.

3.—From prior practice or bench and pilot-scale studies determine suitable treatment for the offending discharges.

4.—Install the plant-scale facilities determined by the results of the studies in step 3.

5.—Continue on, at this point, from step 5 under "Gross Pollution."

Conclusions

In conclusion, the problem of determining the pollutional effects of refinery wastes in salt water is basically the same as the problem of pollutional effects in any watercourse by any industrial establishment. The differences lie in particular subject matter only, and not in the *modus operandi* or the scheme of attack.

The suggested program may serve several functions. It affords the industrial technologist with a planned approach; it emphasizes a practical understanding of pollutional effects and a reasonable approach to abatement requirements; and it attempts to curtail the installation of arbitrary or misdirected in-plant treatment facilities, with little regard for quality objectives, whether they be this year's objectives or those of five, or ten years hence.

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OHIO RIVER TREATMENT REQUIREMENTS

At a meeting of the Ohio River Valley Water Sanitation Commission held on April 2, 1952, the Commission adopted a standard for treatment of sewage discharged to the Ohio River between Huntington, W. Va., and Cincinnati, Ohio. The limits of the river section are defined as U. S. Corps of Engineers Dam No. 27, located about 5 mi. upstream from Huntington, W. Va., and 301 mi. downstream from Pittsburgh, Pa., and U. S. Corps of Engineers Dam No. 36, located about 3 mi. upstream from Cincinnati, Ohio, and 461 mi. downstream from Pittsburgh.

The standard requires:

1. Substantially complete removal of settleable solids.

2. Removal of not less than 45 per cent of the total suspended solids.

3. Reduction in coliform organisms in accordance with the following schedule:

(a) Not less than 90 per cent reduction during the months May through November.

(b) Not less than 80 per cent reduction during the months December through April.

RELATIONSHIP OF AQUATIC FUNGI TO WATER POLLUTION

By James V. Harvey

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This paper is an initial report on studies designed to determine the role of fungi in stream sanitation and processes of natural purification. Considerable information may be found relative to individual groups of fungi which may be dispersed by water. For instance, the literature reports fungal plant pathogens active in a wet environment, fungal parasites which may kill young fish or fish roe in hatcheries, and fungi which attack such materials as textiles, leather, or plastics under wet or extremely moist conditions. Extensive taxonomic studies have been published concerning the true water molds, isolated both from water and soil. Only limited study has been made of water itself, contaminated or pure, as a medium for the growth or transportation of fungi.

When water carries even a small amount of organic matter, fungal activity should be anticipated. Although very few fungi have been seen actually living in water, their spores may be obtained therefrom plentifully. This fact becomes especially interesting when it is noted that many of the species in culture appear to thrive only in such an environment.

Because the stream has been used in similar studies with other forms of life, Lytle Creek, a short tributary of Todd's Fork of the Little Miami River, in Clinton County, Ohio, was chosen

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TABLE I.—Distribution[1] of Fungi Isolated; Lytle Creek, 1951

Organism	Collection Station										
	Clean Water			Septic Zone			Zone of Recovery		Clean Water		
	10.4	9.3	8.7	7.6	7.2	6.5	5.2	4.2	2.8	1.0	0
Saprolegnia ferax	—	—	—	—	—	—	P[2]	—	—	—	—
Saprolegnia delica	—	—	P	P	—	—	—	—	—	—	—
Achlya flagellata	—	—	P	—	—	—	—	—	—	—	—
Dictyuchus sp.[3]	—	—	A	—	—	—	P	—	—	A	—
Aphanomyces laevis (?)	—	—	P	A	—	A	—	A	—	—	—
Brevlegnia diclina	P	P	—	P	—	—	P[2]	—	—	P	—
Brevlegnia subclavata	—	—	—	P	—	—	—	—	—	—	—
Geolegnia septisporangia	—	—	—	P	—	—	—	—	—	—	—
Allomyces sp.	—	—	—	—	—	—	P	—	—	—	—
Pilobolus sp.	—	—	—	—	—	—	—	P	—	—	—
Cephalosporium sp.	—	—	P	—	—	P	P	—	—	—	—
Trichoderma sp.	—	—	—	—	—	—	—	—	—	P	—
Geotrichum sp.	—	—	P	—	—	P	P	—	—	P	—

[1] P = present; A = abundant.
[2] Following rains, the volume of the creek increased, diluting pollution.
[3] Fruiting; non-fruiting.

for a study of the relation of fungi to stream waters of different pollutional content. Lytle Creek drains an upland farm area and receives the effluent from the sewage plant of Wilmington, Ohio.

The sampling stations on the creek were those previously chosen for study by the Biology Section of the Environmental Health Center. Certain physical and chemical characteristics of the water at these stations have been tabulated by Gaufin and Tarzwell (2). Table I indicates the distribution of fungi isolated from these stations during 1951.

Of the 525 samples reported on, 174 were taken from other streams in the Little Miami River system, as well as from the neighboring Great Miami River. Because most of the streams in the former system drain rural areas, little pollution was expected beyond that received from barnyards and septic tanks. The streams sampled, together with the number of samples from each, were:

351 Lytle Creek Basin (including tributaries)
18 Todd's Fork
20 Cowan Lake
18 Cowan Creek
15 Stonelick Creek and Reservoir
28 Little Miami River
38 Little Miami River (miscellaneous tributaries)
36 Great Miami River

Table II lists the fungal species isolated from each stream.

Representative sampling was attempted at each sampling station. The Great Miami River samples were obtained at three stations over a 24-hr. period at 2-hr. intervals. Cowan Lake samples were taken at several depths with Kemmerer jars in similar bihourly samplings over a 24-hr. period. Cowan Lake supplied the only sediment-free samples of water tested. All other "water" samples included stream bottom sediment, such as silt, sand, gravel, and organic debris. Soil samples were also taken from the banks of streams. This material had been submerged during periods of increased water level.

Isolation techniques were those frequently used in such investigations. For water molds belonging to the Phycomycetes the method of Harvey (3) was used. Using this method, a soil sample in a Petri dish was diluted with 15 ml. of sterile distilled water and halved hemp seed was placed face down so that the line of contact was reasonably well aerated. Halved hemp seeds were similarly placed in water samples to "trap" water molds. For Fungi Imperfecti usually associated with soil, soil and water samples were plated with standard dilution techniques on cornmeal and potato dextrose agars. In some cases antibiotics, such as streptomycin, penicillin, and actidione, were added to agar and water media to inhibit the growth of other organisms and thus to encourage the growth of fungi not ordinarily isolated.

Using these techniques, members of the *Saprolegniaceae* usually appeared first within 3 to 7 days. Certain groups tended to lag and others were somewhat erratic. Some representatives of the Fungi Imperfecti appeared, using the water mold technique, as did some members of the *Mucoraceae*.

Discussion

Of the water molds isolated from streams, it appears that the largest number of isolates and species is associated with clear or non-polluted water. Only isolates of *Aphanomyces* and *Allomyces* are associated with polluted water. So far as these studies have gone, *Allomyces* has never been isolated from non-polluted samples, whereas *Geolegnia* has not been isolated from samples with any degree of pollution. Occasionally isolates of *Saprolegnia*, *Achyla*, *Dictyuchus*, *Brevilegnia*, and *Pythium* have

TABLE II.—Distribution of Water Molds and Other Fungi in Southwestern Ohio Streams

Fungus	Streams
	(*a*) SAPROLEGNIACEAE
Saprolegnia ferax	Lytle Creek, Stations 5.2[1], 6.5, 7.2, 7.6 Lytle Creek tributaries Todd's Fork West Fork of East Fork, Little Miami River
Saprolegnia delica	Lytle Creek, Stations 7.6, 8.7 Lytle Creek tributaries Todd's Fork Stonelick Lake East Fork, Little Miami River Roadside spring near Lebanon Stream at bridge No. 43, O.S.R. No. 3, Montgomery
Saprolegnia sp. No. 1	Lytle Creek Basin Little Miami River tributaries
Saprolegnia sp. No. 2	Lytle Creek Basin
Achlya flagellata	Lytle Creek, Station 8.7 Lytle Creek tributaries Stonelick Creek East Fork, Little Miami River, and tributaries
Achlya americana (?)	Lytle Creek Basin
Achlya sp.[2]	Lytle Creek Basin
Achlya sp.[3]	Lytle Creek Basin
Dictyuchus sp.[2, 3]	Lytle Creek, Stations 1.0, (5.2), 8.7 Lytle Creek tributaries Todd's Fork Little East Fork, Todd's Fork Cowan Creek Little Miami River Great Miami River (New Baltimore, Miamitown)
Aphanomyces laevis (?)	Lytle Creek, Stations 4.2, 6.5, 7.6, 8.7 Great Miami River (Venice)
Brevilegnia diclina	Lytle Creek, Stations 5.2, 6.0, 7.6, 9.3, 10.4 Lytle Creek tributaries Todd's Fork Stonelick Creek and Reservoir Cowan Creek Little Miami River East Fork, Little Miami River, and tributaries Great Miami River (New Baltimore, Miamitown)
Brevilegnia subclavata	Lytle Creek, Station 7.6 East Fork, Little Miami River
Geolegnia inflata	Lytle Creek Basin Todd's Fork Cowan Creek
Geolegnia septisporangia	Lytle Creek, Station 7.6

TABLE II.—*Continued*

Fungus	Streams
	(*b*) PYTHIACEAE
Pythium debaryanum	Lytle Creek tributaries Cowan Creek Great Miami River (New Baltimore) East Fork, Little Miami River
Pythium ultimum	Cowan Creek East Fork, Little Miami River
Pythium toruloides	Cowan Creek East Fork, Little Miami River
Pythium sp.	Cowan Creek East Fork, Little Miami River
Allomyces sp.	Lytle Creek, Station 5.2 Lytle Creek tributaries East Fork, Little Miami River, and tributaries
	(*c*) MUCORALES
Pilobolus sp.	Lytle Creek, Station 4.2 Lytle Creek tributaries
	(*d*) FUNGI IMPERFECTI
Cephalosporium sp.	Lytle Creek, Stations 5.2, 6.5, 8.7 Stonelick Creek Great Miami River (New Baltimore)
Trichoderma sp.	Lytle Creek, Station 1.0 Great Miami River (New Baltimore, Miamitown, Venice)
Geotrichum sp.	Lytle Creek, Stations 1.0, 5.2, 6.5, 8.7

[1] Volume of water increased after spring rains, diluting pollution.
[2] Fruiting.
[3] Non-fruiting.

been obtained from samples with a mild degree of pollution. Table III gives the species of fungi according to number of isolates from areas of non-pollution, partial pollution, and heavy pollution.

Interpretation of the results of the study is complicated by taxonomic problems. *Saprolegnia*, *Achlya*, *Dictyuchus*, and *Aphanomyces* isolates are obtained, in which it is not always possible to assign a culture to a species because conditions are not conducive to fruiting, although from the characteristics of the culture it can be assigned to a genus. Because of similarities with other cultures the questionable isolate can sometimes be tentatively assigned to a species.

Two species reported here, *Brevilegnia diclina* and *Geolegnia inflata*, have previously been reported by Harvey (3) (4) (5) (6) (7) from soils in scattered localities, whereas the same author (3) reports *Geolegnia septisporangia* as a rare species reported previously only a few times. In all instances the reports made here are

range extensions, as water molds had not previously been studied in the Little or Great Miami River basins.

It is noteworthy that a species of *Pilobolus* appeared when the water mold isolating technique was used. Because it is generally accepted that spores of this mold germinate only after passing through the alimentary canal of an herbivorous animal, the species is generally expected to be associated with barnyard dung and the spores may be assumed to have washed into the sample prior to collecting from such a location. All isolates grew readily in original culture, but failed to respond in subculture, either by spore germination or mycelial transfer.

Of the Fungi Imperfecti which have been isolated, it is interesting that strains of *Cephalosporium*, *Trichoderma*, and *Geotrichum* have been isolated from areas of questionable purity.

Summary and Conclusion

During approximately one year of preliminary study, more than 500 soil or water samples were collected over areas of localized drainages in southwestern Ohio for the isolation of specific groups of fungi. Collection stations were selected in such a way as to represent both polluted and non-polluted sources.

Of the Saprolegniales, species of *Saprolegnia* and *Achlya* persistently have been absent from heavily polluted water and have been seldom found in

TABLE III.—Relation of Aquatic Fungi to Non-Polluted and Polluted Areas[1]

Genera and Species	Areas Free of Pollution		Areas of Partial Pollution		Areas of Heavy Pollution		Total
	Water[2]	Soil	Water[2]	Soil	Water[2]	Soil	
Saprolegnia ferax	26	7	1	1	—	—	35
Saprolegnia delica	10	3	1	—	—	—	14
Saprolegnia sp. No. 1[3]	5	—	1	—	—	—	6
Saprolegnia sp. No. 2[3]	2	—	—	—	—	—	2
Achlya flagellata	10	1	—	—	—	—	11
Achlya americana (?)	—	1	—	—	—	—	1
Achlya sp.[4]	8	2	1	—	—	—	11
Achlya sp.[3]	20	5	2	—	—	—	27
Dictyuchus sp.[4]	12	—	4	—	—	—	16
Dictyuchus sp.[3]	49	20	9	—	—	—	78
Aphanomyces sp.[4]	2	—	—	—	4	—	6
Aphanomyces sp.[3]	18	7	2	1	2	1	21
Brevilegnia diclina	16	40	10	4	—	—	58
Brevilegnia subclavata	—	3	—	—	—	—	3
Geolegnia inflata	6	23	—	—	—	—	29
Geolegnia septisporangia	—	1	—	—	—	—	1
Pythium debaryana	15	20	4	—	—	—	39
Pythium ultimum	2	3	—	—	—	—	5
Pythium toruloides	3	—	—	—	—	—	3
Pythium sp.	1	5	—	—	—	—	6
Allomyces sp.	—	—	—	4	—	2	6

[1] Numbers indicate the number of times the species was isolated from water or soil samples.

[2] "Water" indicates a stream bottom sample, which contains such sediment as silt, sand, gravel, and organic debris.

[3] Non-fruiting—that is, not bearing oogonia and antheridia.

[4] Fruiting—that is, bearing oogonia and antheridia.

partially polluted places; *Dictyuchus* sp. and *Brevilegnia diclina* followed much the same pattern, as well as the Pythiaceous species represented by *Pythium debaryanum*. *Brevilegnia subclavata*, *Geolegnia inflata*, and *G. septisporangia* were not found in contaminated water or soil. Of the "true" water molds, only *Aphanomyces* showed some affinity for polluted water.

The strains of *Aphanomyces*, *Cephalosporium*, *Trichoderma*, and *Geotrichum* isolated require further study to determine their role in polluted waters.

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The Hotel Statler at New York City, headquarters for the Twenty-Fifth Annual Meeting of the Federation in October, has set aside ample accommodations for the out-of-town registrants.

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WRITE NOW FOR YOUR RESERVATIONS!

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

RECOVERY OF STOLEN PLANT CAPACITY

Capacity of sewers, pumping stations and treatment plants can be "stolen" by undesigned-for storm and surface water just as effectively as though the units were taken partially or entirely out of service. Particularly is this true for sanitary sewer systems in areas where storm-water and surface-water drainage facilities are inadequate to handle heavy flash rainfalls.

Some of the hydraulic and public relations problems involved in one such situation are briefly described elsewhere in this "Corner." Also described is the approach used by one California sanitary district in solving these problems. Those who have experienced the results of such unthinking actions of the public as are reported will be particularly interested in the practical and logical procedures used in the solution of the problems.

All too often those who have met these problems head on are reluctant to discuss them. But it is only through exchange of experiences that certain avoidable deficiencies in sewer systems can be brought to light and emphasized. It is with this thought that the author has presented the present paper, in the hope that it will stimulate wider discussion.

Admittedly, sewer specifications and types of construction good in one locality may not be suitable in others. This phase of the problem of sewage collection and treatment has, however, been sadly neglected. Hardly a sewer system exists where storm flow has been completely eliminated, despite ordinances forbidding storm-water connections and despite constant vigilance on the part of system administrators. Much of the trouble is traceable to poor construction coupled with inadequate inspection. Nevertheless, a good deal is also traceable to lax enforcement of existing ordinances or regulations. A few roof drains or a flooded manhole top may not seem important in themselves, but in the aggregate it does not take many such unwarranted storm-water entry points to effectively rob your sewers and your treatment plant units of sizeable fractions of their capacity.

The "thief" has been identified as a "public enemy" for a long time. Rising costs of construction and operation, however, make more energetic pursuit a must if these costs are to be kept within permissible budgets. There are no doubt many cases where return of the capacity "stolen" by storm water will restore to present usefulness a system now grossly overloaded, or may eliminate the need for costly additions. As Mr. Sauer so ably puts it: "The District, it must be remembered, is in the sewage, not the storm-water business."

H. P. O.

STORM WATER IN SANITARY SEWERS*

By Victor W. Sauer

Former Acting District Engineer, Central Contra Costa (Calif.) Sanitary District

The matter of storm water getting into sanitary sewers has been considered a taboo subject which should not be discussed except behind locked doors, and the details of such discussion should be considered "top secret." On the other hand, all phases of the design, construction, and operation of sewage treatment plants have been and are receiving full detailed attention from engineers, research men, and operators. The sewer system, which may cost from 10 to 20 times as much as the treatment plant, in many instances has been sadly neglected. A careless design, along with poor or inadequate inspection, is not a proper safeguard for a good system. There are many plants that are well designed and constructed, but which can not function properly because there are enormous differentials in the rates of flow, due to infiltration of storm water.

Description of District

Before going into details, a few general comments concerning the Central Contra Costa Sanitary District are proper. The District was formed in 1946 under the provisions of the Sanitary District Act of 1923, and is a political subdivision of the State of California. The District as formed and with subsequent annexations has an area of approximately 50 sq. mi., or 30,000 acres. To date the main trunk sewers, the treatment plant, five pumping plants, and 275 mi. of collecting sewers have been constructed and are in operation. Also, about 200 mi. of side sewers are now connected to the collecting system, serving 39,000 people.

The general topography of the District ranges from very rugged hill country, through rolling topography, to flat table land. The type of soil varies greatly, ranging through rock, clay, adobe, loam, and all possible combinations thereof. The adobe soil swells in the winter and cracks in the summer, which action is particularly bad on shallow side sewers. A large area of the District is the unstable Orinda formation, which was laid down in a fresh-water lake. Slides involving sewers and streets are very common.

Starting at the western end of the District, a large acreage in Orinda contributes to the lower Orinda pumping station, which lifts the sewage to the upper Orinda relay and collecting pumping station, which in turn lifts the sewage to the portal of a tunnel. From the portal of the tunnel the main trunk sewer, 13 mi. in length, flows easterly from the Orinda area into the Lafayette area, at which point the Moraga Valley trunk lateral joins the main trunk sewer. The Moraga Valley area also has two small pumping stations in series, which lift the sewage by stages into the gravity portion of the Moraga Valley sewer. A large portion of this valley is in the San Leandro watershed of the East Bay Municipal Utility District. From the above junction point the main trunk sewer pursues its course easterly through Saranap and through the city of Walnut Creek. Thence the course of the sewer is northerly through the Pleasant Hills area and the town of Pacheco to the treatment plant located on the Arnold Industrial Highway northeast of Pacheco, which formerly was the county seat of what is now Alameda and Contra Costa Counties.

* Presented at 1952 Annual Meeting, California Sewage Works Assn.; Santa Cruz, Calif.; April 23–26, 1952.

Storm-Water Flooding

All went well in the functioning of the treatment plant, which started operation in September, 1948, and in the sanitary sewer system, until the winter of 1950–51. Then the lower Orinda pumping plant, due to the excessive storm water, was flooded out and by-passed sewage into a creek tributary of the San Pablo reservoir, which is a water supply source for the East Bay Municipal Utility District. In portions of the Lafayette area the main trunk sewer became surcharged and water escaped through manhole tops into streets and yards. At the treatment plant, which then had a pumping capacity of approximately 9 m.g.d., it was necessary to choke down the main trunk sewer and surcharge the line back a considerable distance to prevent flooding the plant. The by-passes provided at the sewage treatment plant were of such elevation that during storm flows the creek that runs alongside of and would receive by-pass waters from the treatment plant had a much higher elevation than the by-passes.

Sewer System Survey

A survey of the sewer system revealed certain defects, which were corrected; but time, manpower, and funds limited the amount that could be discovered and corrected. Throughout the District structures were checked for defects due to construction or defects arising after construction due to earth movements or other disturbances. Along with the structures, certain sewer lines were found to be defective (poor joints and shallow lines) and were repaired. The section of the main trunk sewer from the treatment plant to Walnut Creek was checked by special crews, who crawled the line. The crews were equipped with gas masks, rubber suits, and two-way telephone communication. The main trunk sewer ranged in size from 24-in. to 39-in. diameter and the minimum flow was 10 in., which conditions made the work slow, tedious, and dangerous.

The condition of each 8-ft. length and each joint was noted and recorded. The pipe barrel was in excellent condition, but several joints were found to vary in leakage from drips or ooze to small pencil streams. However, the amount of leakage from these joints was insignificant compared to the quantity of storm water being sought, so this section of the sewer was passed for the time being. Also, the pumping capacity of the upper and lower Orinda stations and the treatment plant was increased to help carry the additional load, to provide stand-by capacity, and to provide for the present and future rapid growth.

After the rainy season of 1950–51 and throughout the following spring and summer the sewer system and plant operated satisfactorily. In fact the total flow during the summer of 1951 was less than the allowable infiltration, using the formula of 1,000 g.p.d. per inch diameter per mile of pipe. In the winter of 1951–52 there was a repetition of events of the previous winter. At this time it was realized that a long-term intensive program of investigation and corrective maintenance would have to be set up, and the District Board has ordered this to be accomplished.

New Program

A program was set up to check the entire Sanitary District with District personnel who would otherwise be laid off because the construction program was slowing down. The sewer districts in that portion of the Sanitary District lying above the San Pablo reservoir and feeding to the lower and upper Orinda pumping stations were chosen first. Two types of inspection teams were organized: one to check on roof leaders and yard drains, the other to check on structures and sewers.

The sewer lines were investigated by

taking at least three dry-weather readings and three wet-weather readings at each manhole in the following manner. A stick was first laid across the open manhole. Then a graduated measuring stick was lowered until it touched the surface of the liquid in the manhole channel, and then dropped to the bottom of the channel. Readings or estimates were also made on the condition of flow in the branch lines entering the manholes.

This method of measuring is crude, but close enough for the present purpose. The thing sought was not small differentials, but rather variations of from 0.5 to 4 in. Many such variations were found, and the defective lines were isolated between structures. Nearly all of the defective lines were in rights of way and were shallow—24 to 42 in. in depth. The lines with the greatest "jump up" in flow are scheduled for first repairs or reconstruction.

At the same time, structures were found that leaked badly, but these can be readily repaired at small cost. The wet-weather readings are best obtained in hard driving rain, so the crews also worked on Saturdays and Sundays if the rainfall was heavy.

An investigation was also made on structures as to the amount of water that could be contributed through their tops during rains. An understanding of the conditions of the area in contrast to the usual city development is necessary to appreciate fully this source of storm-water leakage. Streets are, for the most part, flat and poorly drained. During heavy rains water sheets over the streets in depths from ¼ in. to extreme conditions where water a foot or more deep stands in streets and yard areas from several hours to days at a time.

Several structures taken at random through the area were investigated in the following manner—a small circular clay dam was built around the manhole and 5 gal. of water was dumped inside the dam, giving an initial head of about 2 in. over the structure top. It was found that the structures would take from no appreciable water up to 18 g.p.m., and that a very high percentage of structures would take from 3 to 6 g.p.m. Also, if the water was poured slowly over the structure top in contrast to pouring it in all at once the amount getting into the sewer per minute was, for all practical purposes, the same in both cases. This was thought to be most significant, inasmuch as there are 3,500 structures in the Sanitary District, several hundred of which are totally inundated for long periods of time during heavy rainfall. Others are subjected to rain sheeting over the streets.

Sewers Used as Flood Outlets

Another, and quite unusual, cause of large amounts of water getting into the system was found by the inspection forces. Individuals in street and yard areas where drainage was very poor would, when water was covering the streets and yards and threatening to invade the homes, prop up the manhole covers in the low spots with bricks or other devices and drain off the entire area. On certain days when this situation was found, a check at the treatment plant revealed sudden jumps in the pumping rate of 4 m.g. within 30 min.

The structure and sewer teams also uncovered another interesting situation in certain right of way areas through yards and fields where shallow sewer lines had been installed. Hoses were put in gopher holes and the water turned on. After 5 to 10 min. there was an appreciable increase in flow at the next lower structure. This was true of certain lines that had been observed during heavy rainfall to have large "jump ups" in flow. In all cases of this type of sewer line the heavier the rainfall the heavier the flow. There had been considerable controversy and discussion in the Dis-

trict office as to whether rains could penetrate the ground rapidly and add to the "jump ups" in flow through poor joints. We are convinced now that in certain areas the amounts can be of considerable consequence.

Roof and Yard Drains

The roof leader and yard drain teams carried on their functions along with the structure and sewer teams. The procedure in this case was to check, with 2 or 3 gal. of dyed water, every roof leader that went underground. To date there have been approximately 24 roof leader connections discovered in the area surveyed and the indications are that many more will be discovered.

The activities cited are an outline of investigations carried out, and all possible time will be devoted to the program of investigation and correction prior to the next rainy season.

The program of roof leader and yard drain survey will be carried out through each of the 11,000 connected houses. Where such connections are found, they will be disconnected under District inspection. Along with this course of action, wide-spread publicity will be given to all individuals, through newspapers and direct contact with improvement clubs in the area, as to the adverse effect roof leaders and yard drains have on the sewer system.

All structure tops, whether in streets or yard areas, that are subject to flooding or sheeting over with water will be sealed down with either hot tar poured around the ring and edge of the lid and in the lifting hole, or by means of a cold-mix bituminous material. In addition, manholes in yard or street areas that ingenious individuals might lift to drain low areas will be electrically welded. It has been found that brazing of the cast-iron ring to the frame does not work, but strips of steel can be welded to the frame and cover and will securely hold the assembly together. Such manholes can be beaten with a sledge hammer, have heavy trucks driven over them, and apparently are proof from lifting by persons not equipped with a cutting torch.

Joint Leakage Correction

As far as collecting or lateral sewers are concerned, several hundred feet have been isolated which had excessive amounts of infiltration. The joints will be uncovered and remade, and broken pipes will be replaced. Another phase of corrective work being accomplished is that sewer crossings from street to rights of way under ditches, creeks, and swales are being uncovered. Since the installation of the sewers, residents and county forces have increased the depth of small waterways and drainage ditches, thereby decreasing the cover and damaging the District's sewers. One case was found in particular where a road grader had knocked off the top of an 8-in. sewer, which was left exposed in a gutter area where a large acreage above fed a stream of water to the sewer. Another typical case was found where a shallow cast-iron line in a waterway had been subject to washing. The cast iron separated by dropping away from the vitrified clay connection, enabling the sanitary sewer to function as a storm sewer.

Treatment Plant Improvements

At the sewage treatment plant a contract has been awarded to install a gasoline-powered stand-by unit, which by itself can pump the full line capacity of the main trunk sewer directly through the header to the oxidation ponds. This installation will supplement the electric units and provide an independent adequate capacity in the event of a power outage.

In addition to the other troubles, the main pressure line between the lower and upper Orinda pumping stations has failed for the second time due to slides, and a new location approved by

a geologist has been found. The planned installation in this locality is an ultimate-size line for the ultimate built-up Orinda area. The effect will be to increase immediately the pumping capacity from the lower to the upper station by a large amount, and as the work of correction in the Orinda area proceeds there will be more and more capacity available in the line for sewage. The District, it must be remembered, is in the sewage, not the storm-water business.

Summary

It is felt that when the rainy season of 1952–53 comes on, the District's sewer system will be in much better shape by the exclusion of all known roof and yard leaders, the sealing down of manhole covers and the repairing of a certain number of defective lines.

Certain steps have been taken to prevent additional trouble. All future installations of collecting sewers or side sewers will not, with the new specifications submitted for approval, contribute any appreciable amount of storm water to the system. The collecting sewers and side sewers will be given water tests such as are carried out by the cities and counties of Los Angeles and San Diego.

A final thought is that the installation of sewer systems should be carried out with great care, starting with design, continuing through a complete and rigorous inspection of construction, and ending in a program of continued preventive maintenance.

THE DAILY LOG

Plainfield (N. J.) Joint Meeting

By Andrew Palmer, *Superintendent*

August 1—Had some visitors today who wanted to look over our effluent recirculation for fly control on the trickling filters. They could not get over how well we were able to control this nuisance, as no flies were observed on the wing. We explained to them that the maximum capacity of the nozzle field at mean head in the dosing tanks is established and enough filter effluent is pumped back to the dosing tanks to maintain this flow at all times. Butterfly valves on the outlets of the dosing tanks are operated by ¼-hp. motors on a 35-sec. cycle from zero to full head. By this arrangement the umbrella-like conformation of the spray is constantly changing from zero to full spread of 14 ft. so that every part of the bed area is continuously covered.

August 2—Our plant chemist decided to run a complete chemical analysis test for 24 hr. These tests are run about once a month and are very interesting in that they show the hourly fluctuations in the sewage as it passes through the various units of the plant.

August 4—Unloaded a multi-unit tank carload of chlorine this morning. Made very good time, considering that the railroad siding is nearly 5 mi. from the plant. The job was completed in about 3 hr. The day being hot, this called for cooling refreshments and a short rest for all hands.

August 7—This morning the superintendent of an industrial waste treatment plant came in to look over our plant and to ask if we would give him enough seeding sludge to start two digesters. He was told that we would give him as much as he wanted. He had already made tentative arrangements with a trucker who had suitable equipment and they expected to start hauling the next day.

August 9—The night man reported that he had some trouble with the

chlorine feed line to the chlorinator at the final settling tanks. It was found that the valve had become corroded—after cleaning it out, it worked very well.

August 10—Today 27 student nurses of the sophomore class of Muhlenberg Hospital visited the plant. They were given a complete tour of the plant, with explanations of the functions of the various units, and were also shown several tests being made. They were surprised that we undertook to run these tests at a sewage disposal plant.

August 12—The long dry spell was finally broken last night with a very heavy thunderstorm. Lightning struck a power transformer on the line feeding the plant and we were without power for about 2 hr.

August 15—While a couple of men were cleaning out the grit chamber this morning they found a $20 bill and a $5 bill. Now they will make a closer examination of the grit when they clean the grit chamber. Incidentally, this is the first money they have found in about a year.

August 21—The industrial plant that has been getting seeding sludge called this morning to say they had enough sludge and to thank us for giving them a start.

August 25—Another Friday inspection of our 7-mi. trunk line. Decided to have the brush and weeds along the right-of-way cut so that inspections can be made more easily.

August 28—Continuing where we left off on Friday, we spent most of today inspecting manholes for repairs to be made before cold weather sets in. Found several that needed small repairs, also several places where we cross small brooks which had to be cleaned out to allow surface water to flow more freely.

August 30—In checking over the plant chemist's report for the month on the eight digesters, we found that they were doing a bang-up job. The pH averaged 7.2. Moisture averaged 94.5 per cent. The volatile matter averaged 51.4 per cent.

The average daily 5-day B.O.D. for the various plant units was as follows: raw sewage, 223 p.p.m.; primary settling tank effluent 114 p.p.m.; trickling filter effluent, 15 p.p.m.; and final effluent, 14 p.p.m.

Daily average flow for the month was 5.11 m.g.d.

September 1—This morning the sludge pump at the final setting tank was found to be in need of repairs. It was replaced with the spare pump and dismantling was started. The impeller was badly worn, as was the diffuser. New parts were ordered to replace the worn-out parts.

September 5—Back from a Labor Day weekend spent on the Jersey coast, where we did some surf fishing, but without catching a thing except a good sized sand shark. Expect to try it again soon.

September 7—The parts for the 3-in. sludge pump were received and given to the mechanic, who immediately went to work on the final settling tank sludge pump.

September 8—The operator of a neighboring municipality's disposal plant called and asked if we could help him out in doing some welding for him. Our welder was sent over and was back in about 3 hr., having completed the job.

September 11—The men were all out on the trunk sewer making masonry repairs to manholes which we had found in need of some new brick and the replacing of bad concrete.

September 12—It rained today, so the men have been working in the shop all day, metallizing an atomizer shaft and finishing up the reassembling of the sludge pump.

September 14—Busy plowing fire breaks for the prevention of field fires around our 25 acres of young white pine trees, which are now about 10 ft. tall. These trees were planted by WPA labor in 1932 and certainly look

very good. This is a yearly task and has proven a good insurance more than once.

September 15—A few Joint Meeting councilmen made a visit to the plant this afternoon. They were well pleased with the appearance of the plant and gave the plant personnel a pat on the back for the interest they take in their work.

September 19—Putting a new roof on our sludge drying tower today. A number of sparrow nests were found under the eaves. Some of these pests seem to think they own the place!

September 21—Planted honeysuckle vines on the earth banks around the two new digesters, having just completed building them up to the desired height and slope. This makes an excellent protection against erosion, as well as a pleasing appearance.

September 23—Spent all morning making a plant inspection. Everything was in very fine condition, except some steel sash which need to be wire-brushed and repainted.

September 25—A group from another of the neighboring municipalities visited the plant to look over our fly control on the sprinkling filters. They are having some trouble with flies and had heard about our success in combatting this nuisance.

September 28—The city engineer came in to see how we metallize and rebuild worn pump plungers. He was given quite a demonstration, after which he promised to send us some of his equipment to rebuild. This helps to build a closer cooperation between various municipal departments.

September 29—A group of Boy Scouts visited the plant this afternoon in connection with Public Health Merit Badge work. The functions of a sewage treatment plant were explained in relation to the public health of the community. A most interesting group of boys.

September 30—While cutting the grass along the banks of the trickling filters with the sicklebar mower, one of the men ran into—and out of—a nest of yellow jackets. The mower was finally rescued from the angry wasps and the nest was burned out. The hustle exhibited during the crisis was, however, really a little "over and beyond the call of duty," even at a sewage treatment plant!

ORGANIZATION OF THE LOS ANGELES SEWER MAINTENANCE DIVISION *

By Alvin A. Appel

Superintendent, Sewer Maintenance Division, Bureau of Sanitation, City of Los Angeles, Calif.

The Sewer Maintenance Division of the Bureau of Sanitation, Los Angeles Department of Public Works, is responsible for controlling the discharge of sewage and storm-water wastes into sewers, storm drains, open channels, and navigable waters, which includes the maintenance, operation, and repair of all sanitary sewers, storm drains, culverts, and appurtenant structures, as well as sewage and storm-water pumping plants, sewer ventilating plants, and the Terminal Island sewage treatment plant; the control of the discharge of industrial wastes from all industries into sewers, storm drains, and ditches; the detection and elimination of explosive gas from sewers and storm drains; and the inspection and

* Adapted from "Annual Report, City of Los Angeles Sewer Maintenance Division, 1950–51."

TABLE I.—City of Los Angeles Sewer Maintenance Division Personnel, 1950—51

Superintendent	1
Asst. superintendent	1
Indus. waste engineer	1
Civil engineering asst.	1
Channel maint. engineer	1
General foremen	2
District foremen	3
Clerks	6
Senior indus. waste insp.	1
Indus. waste inspectors	9
Working foremen	35
Truck operators	7
Brick mason	1
Painter	1
Carpenter	1
Equipment operator	1
Warehouseman	1
Electrician foreman	1
Electricians	3
Maintenance laborers	62
Maint. and const. helpers	26
Sewage plant operators	2
Plant attendants	5
Elec. pumping plant oper.	12
Chief sew. treat. plant oper.	1
Mechanical repairmen	4
Total	189

maintenance of open storm-water channels. There are 3,540 mi. of main line sewers and 763 mi. of storm drain.

Organization

The Division is organized into an administrative section and five operating sections with a total personnel of 189 men. The force is comprised as shown in Figure 1 and Table 1.

Administration

The Administrative Section provides general direction for all of the operating functions of the Division, and furnishes such information or services as are necessary for the most efficient accomplishment of the work. The personnel consists of one superintendent, one assistant superintendent, one civil engineer assistant, and three clerks.

This section is responsible for the maintenance and preparation of routine records and reports, including a yearly budget request and annual report, and for such special technical or administrative reports and correspondence as required.

Pipe-Line Maintenance

The Pipe-Line Maintenance Section is under the direction of a general foreman and is responsible for the inspec-

BUREAU OF SANITATION
DEPARTMENT OF PUBLIC WORKS
CITY OF LOS ANGELES
SEWER MAINTENANCE DIVISION
SEWER MAINTENANCE SUPERINTENDENT
ASS'T SEWER MAINTENANCE SUPERINTENDENT
GEN. ADMINISTRATION OFFICE
ANALYTICAL, STATISTICAL, AND CLERICAL STAFF
PIPELINE MAINTENANCE
MAINTENANCE, INSPECTION, AND OPERATION OF SEWER AND STORM DRAIN SYSTEM
OPERATION & REPAIR
MAINTENANCE, OPERATION, AND REPAIR OF ALL PUMPING PLANTS, VENTILATING PLANTS; MAINTENANCE AND REPAIR OF PLANTS AND PORTABLE EQUIPMENT; REPAIR SHOP; WAREHOUSE
INDUSTRIAL WASTE CONTROL
INVESTIGATING, TESTING, PERMITS, INSPECTIONS, SPECIAL STUDIES, WATERCOURSE AND HARBOR POLLUTION
TERMINAL ISLAND SEWAGE TREATMENT PLANT
OPERATION AND MAINTENANCE
CHANNEL MAINTENANCE
INSPECTION, CLEANING, BANK PROTECTION, AND PROTECTIVE FENCING

FIGURE 1.—Organization chart for City of Los Angeles Sewer Maintenance Division.

tion and maintenance of all city sewers, storm drains, and culverts. There are five district yards from which these operations are conducted.

The North District Yard personnel is composed of 59 men as follows: one district foreman, one working foreman acting as a construction foreman, one 4-man storm drain cleaning crew, one 3-man culvert cleaning crew, four sewer and storm drain maintenance crews totaling 12 men, one equipment operator, one clerk, one yard man, one city-wide bricklaying crew of 3 men, one city-wide machine cleaning crew of 3 men, two night and week-end emergency crews totaling 6 men, two city-wide catch basin clean-up crews totaling 4 men, one city-wide sewer and storm drain maintenance crew of 3 men, three city-wide construction and deep-sewer repair crews totaling 10 men, one city-wide sewer motor flusher crew of 2 men, and two sewer flushing crews totaling 4 men.

The South District Yard personnel is composed of 32 men as follows: one district foreman, two storm drain cleaning crews totaling 8 men, two sewer and storm drain maintenance crews totaling 6 men, two catch basin clean-up crews totaling 4 men, one yard man, one city-wide machine cleaning crew of 3 men, two city-wide construction and deep-sewer crews totaling 7 men, and one sewer flushing crew of 2 men.

The West District Yard personnel is composed of 19 men as follows: one district foreman, one 4-man construction and repair crew, one 3-man sewer and storm drain maintenance crew, one 3-man machine cleaning crew, one 4-man storm drain cleaning crew, one 2-man catch basin clean-up crew, and one sewer flushing crew of 2 men.

The Valley District Yard personnel is composed of one working foreman acting as a district foreman, one 3-man sewer and storm drain maintenance crew, and one sewer flushing crew of 2 men. Because of the increasing work load in this rapidly expanding district of the city, it has been necessary to augment this crew with deatchments from the North District Yard at intervals to provide assistance in maintaining routine work.

The Harbor District Yard personnel is composed of one working foreman acting as district foreman, and a 3-man sewer and storm drain maintenance crew.

Channel Maintenance

The Channel Maintenance Section works under the general supervision of the channel maintenance engineer, who is responsible for the maintenance of city channels and the protection of abutting property. The channel crew is composed of one working foreman and ten men.

Operation and Repair

The Operation and Repair Section operates under the general supervision of a general foreman, who is responsible for the operation of sewage and storm-water pumping and sewer ventilating plants; for mechanical and electrical maintenance of plants and equipment; for certain electrical maintenance as required at installations of the Refuse Collection and Incineration Division of the Bureau of Sanitation; for the checking of design of electrical components, including motors and controls, of new plants; and for the testing for explosive gases in sewers. The crews of this section include 29 men, as follows: one plant operation crew of 12 men, one 2-man explosive gas survey crew, one 3-man shop crew, one painter, one carpenter, one 4-man mechanical maintenance crew, one warehouseman, one clerk, one electrician foreman, and three electricians.

Industrial Waste Control

The Industrial Waste Section operates under the direction of the indus-

trial waste engineer, who is responsible for control of industrial discharges into sewers, storm drains, and channels. Personnel in this section consists of one senior industrial waste inspector, nine industrial waste inspectors, and one clerk.

Sewage Treament Plant Operation and Maintenance

The sewage treatment plant at Terminal Island is under the general supervision of the chief sewage treatment plant operator, who is responsible for the operation and maintenance of the plant and reports directly to the superintendent of the Division. Plant personnel further consists of 2 plant operators and 5 plant attendants.

Operations, 1950–51

Some idea of the magnitude of the Division's activity can be gained from the following sketchy outline of some of the more important projects during the 1950–51 fiscal year.

Pipe-Line Maintenance

During the year, new construction added 123 mi. of main line sewers and 11 mi. of storm drains. This represented a 3 per cent and 1 per cent increase, respectively. 554 taps were made and saddles installed for new house connections, the cost of which was paid for by the property owner and amounted to $7,903 for the year. The cost of raising of lowering manholes at the request and expense of property owner amounted to $1,029. Other preventive and emergency repairs on sewer and storm lines during the year cost a total of $19,386.

Channel Maintenance

As in preceding years, the regular planned program of work and assignment of the regular channel crew has resulted in greatly reducing the need for emergency work during storms and complaints of stagnant water during the summer.

The deficiency of rainfall during the year 1950–51, which totaled only 8.21 in. as compared with the 73-yr. average of 15.24 in., required less channel repair work, thereby permitting a larger amount of work by the channel maintenance section to be spent on projects eliminating standing water in open ditches which otherwise would have been sources of odor or mosquito complaints.

Routine inspections are made of all channels twice yearly—in the spring to determine the effect of the preceding winter's rains and again in the fall to determine their condition with regard to the coming rainy season in order to plan corrective measures. A total of 41 mi. of channel was cleaned of brush and debris.

Operation and Repair

During the year four new sewage pumping plants were placed in operation. Also placed in operation was a pumping plant serving an industrial area adjacent to the Los Angeles International Airport and replacing a temporary pumping plant built by a private concern to take care of the sewage of a subdivision. During the year two other pumping plants were remodeled. There are now 31 sewage and storm-water pumping plants in operation. Four permanent sewer ventilating plants were operated as required, and one temporary ventilating plant was operated on an experimental basis. It proved to be of so much benefit in correcting odor conditions that the construction of a permanent plant was recommended.

The mobile equipment serviced by the Operation and Repair Section is as follows: 25 1-ton or 1½-ton canopy trucks; 8 1-ton or 1½-ton stake trucks; 6 1-ton pick-up trucks; 8 1½-ton to 4-ton dump trucks; 2 1-ton or 1½-ton

panel trucks; 1 station wagon, 1 ¼-ton truck, 1 sewer flusher truck, 3 truck-mounted sewer rodding machines, 1 truck-mounted sewer ventilating fan, 1 2-ton tractor, 1 ¼-yd. skip loader, 1 D–4 bulldozer, 1 D–4 tractor equipped with boom and orange-peel bucket, and 1 5-ton crane.

In addition this Section maintains the following divisional equipment, mounted on either trailers or skids: 30 2-in. to 8-in. pumps, 2 bucket-type sewer cleaning machines, 1 sewer rodding machine, 1 5-kw. generator, 6 air compressors, 4 cement mixers, 1 sewer ventilating fan, 1 10-ton low-bed trailer, and 1 6,000-lb.-per-day and 2 300-lb.-per-day portable chlorinators.

Heavy repair work to trucks was done in the equipment repair shop of the Refuse Collection Division of the Bureau. Light emergency and operating repairs are made in the Sewer Maintenance North Yard repair shop, or in the field when necessary.

The explosive gas survey crew observed 78,138 manholes at an average cost of $0.098 per manhole, and found 51 manholes in which an explosive condition was present, caused by infiltration of illuminating gas. Corrective measures in the latter cases were immediately undertaken, thereby averting serious consequences.

Industrial Waste Control

During the year, 2,493 requests for industrial waste connections were processed. 7,959 inspections were made of sand traps, floor drains, and grease and oil interceptors. It is now estimated that 35,431 industrial locations require yearly inspection to insure that illegal quantities of oils, greases, or other deleterious materials will not enter the sewage system.

The periodic inspection and testing of the Los Angeles River and other open channels or storm drains terminating therein, in order to reduce pollution by industrial waste, was continued during the year. The establishment of a Regional Water Pollution Control Board as a state agency reemphasized the importance of this method of control.

The total cost of industrial waste control amounted to $40,764 and receipts for industrial waste permits and fees amounted to $26,260, resulting in a net cost of $14,504. Functional costs for industrial waste control were in the following proportions: inspection of existing pre-treatment facilities, 26 per cent; special investigations required for new permits, 25 per cent; stream and ground-water pollution investigation, 26 per cent; and administration and research, 23 per cent.

Sewage Treatment Plant

The Terminal Island sewage treatment plant receives and treats sewage originating in the Wilmington, Harbor City, and San Pedro area. The average daily flow for the past year was 5.03 m.g.d. The plant is composed of the following operating units: a hand-raked bar screen; an 85-ft. diameter center-feed clarifier; a 75-ft. diameter digester; 3 sludge concentration tanks; sludge drying beds; a gas holder; and various pumps and appurtenant equipment. The outfall is 1,200 ft. long and discharges into the outer harbor at San Pedro. The digested sludge is removed from the sand beds by a private contractor under an agreement of sale for the sludge at the price of $0.03 per cubic foot of sludge. The gross cost of treatment for the year, excluding depreciation, was $20.70 per m.g. During the year revenue amounting to $949 was received from the sale of dried sludge, which resulted in a net cost of $20.19 per m.g.

Extensive maintenance and renovation of the operating equipment by the Operation and Repair Section has been reflected in an increased cost of treatment per million gallons over the preceding year's figure.

Miscellaneous

During the year construction by the Bureau of Public Buildings of a new Sewer Maintenance West District Yard, located in the Venice area, was completed and occupied by this Division. In addition, a new equipment storage shed was constructed at the North Yard.

SHIFT SCHEDULING MADE EASY

By Frank I. Vilen

Superintendent, Sewage Treatment Plant, Kenosha, Wis.

As in many cities, the Kenosha sewage treatment plant is operated on a three-shift basis, with each of 6 operators changing shifts every week. To average out at the standard work week of 40 hr., each man works alternately a 7-day week of 56 hr. and a 3-day week of 24 hr. In a 6-week shift rotation period, each operator works the midnight to 8AM shift, the 4PM to midnight shift, and the balance of the time on days from 8AM to 4PM.

The shifts also have been arranged to provide as many men as possible for daytime maintenance and repair work. Some cleaning is done on the 4PM to midnight shift. To do this, the days off are staggered so at least three men are available on the day shift for the greater part of the week. Night shift, Saturday, and Sunday operations are carried on by one man per shift. (Incidentally, there is a call arrangement with the police when only one man is on duty. The shift operator calls in on the hour; if he fails to do so, a squad is sent out to see that he is all right.)

Projection of a schedule of this type is tedious, subject to error, and further complicated by the "deals" arranged between the operators to work for each other. There is no objection to this substitution if there is a legitimate reason for a change. Because the so-called "owl" shifts are rather unpopular, however, a rule has been promulgated that time worked for another must be paid back on the same shift.

The problem of arranging vacations also can become quite involved. Obviously, an operator cannot schedule such time off except when he is working days. In addition, problems arise on the six legal holidays, as it is possible for one or two fortunate men to have off more than their share in any one year.

When one of the operators suggested that he could design a gadget that would indicate any man's position on the schedule for any week of the year, the idea was welcomed. Thus was born what for lack of a better name has been christened the "Thing" (Figure 1).

The device was developed from a few Christmas tree lamps, two tin cans, a piece of plywood, some bell wire, and a couple of pull switches. All the work was done on the owl shifts, when time hangs heavy and there isn't much to do. As the pull switches and wire were on hand, the total cost was under a couple of dollars.

How It Works

Here is how it works. The "Thing" consists of a couple of salmon cans (empty, of course), on which are mounted paper tapes printed with the dates of the first day of the plant work week for the entire year. To keep the size of the drums small, the first 26 weeks are indicated on one drum, the last half of the year on another. On the face of the box containing the

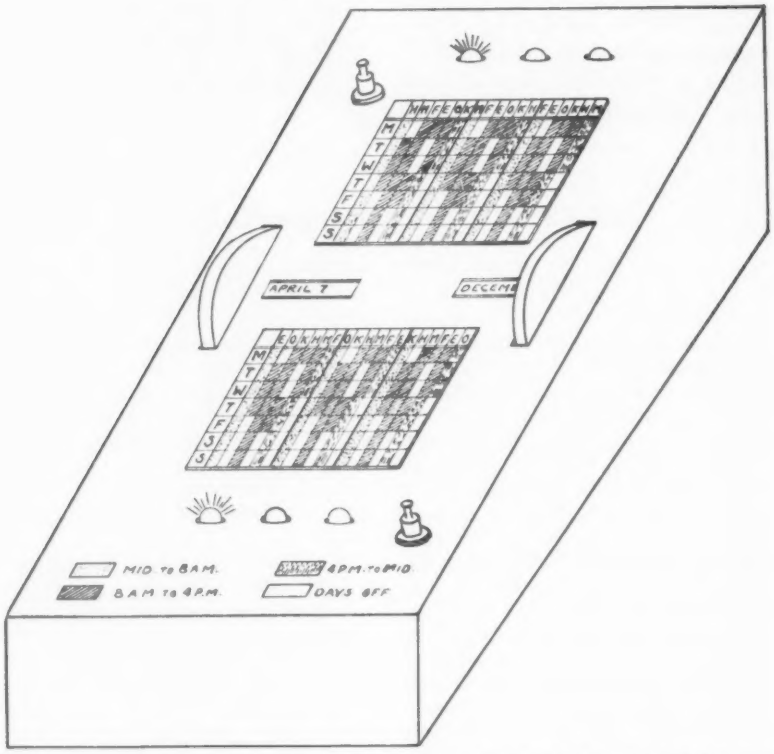

FIGURE 1.—The "Thing" tells who works what shift and who has time off for every day during the year.

drums, contacts, and necessary wiring, is mounted a schedule showing each man's shift allocation during the 6-week rotation period. As the drums are rotated, the lamps light up (through suitable contacts on the can perimeter) to indicate the schedule applicable to any particular week.

To illustrate, suppose Mr. F's wife wants to know whether she can plan on visiting out-of-town relatives over Labor Day weekend. F turns the dial to the week in which Labor Day falls, turns on the switch, and informs his wife that he is very sorry, but the schedule says he works from 4PM to midnight on Labor Day. (Of course, since Labor Day is a legal holiday, he'll get the time off at the next convenient opportunity when he's scheduled on the day shift.) As set up in Figure 1, the upper left-hand light is on to show that schedule as applicable to the week of April 7. The lower left-hand light is on to indicate that schedule as applying to the week of December 1 (right-hand drum).

The "Thing" was designed and constructed by Bernard Organist, operator at the Kenosha plant.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Annual Reports of District of Columbia Sewage Treatment Plant for Fiscal Years 1950 and 1951 *

By Ralph E. Fuhrman, *Superintendent*

The fiscal years 1950 and 1951 saw virtual completion of construction work on four additional sedimentation tanks and four additional sludge digestion tanks. Also, installation of a new 80-m.g.d. sewage pump was completed and work was begun on construction of sludge drying and incineration equipment to permit more economical and satisfactory sludge disposal.

Guggenheim Demonstration Plant

The Guggenheim demonstration plant was operated as such until November, 1949, when experiments by the patentees were concluded. During May, 1950, this pilot plant was converted into a modified aeration type of treatment unit so that plant laboratory experiments could be continued on a larger scale. The purpose of the latter experiments is to determine the adaptability of the local sewage to this type of treatment and optimum conditions for various degrees of treatment.

Gas Engine

The regular gas engine overhaul was not scheduled during 1950, with the result that a new record was established for the total time of engine operation. During the year the gas engine was out of service only 20 hr. and was operated a total of 8,740 hr.

Sludge Dewatering

More uniform operation of the sludge dewatering plant was possible in 1951, because for the first full year since World War II there was no shortage of $FeCl_3$ to curtail operations. This uniform operation was reflected in improved digester overflow and better sewage purification results.

Sedimentation

In former years, population equivalents have been calculated on the basis of 0.20 lb. of 5-day B.O.D. per capita per day. On this basis the equivalent population served by the plant averaged 819,200 in 1951. The widespread use of synthetic detergents instead of soap tends to lower the population equivalent values, as the B.O.D. of the syndets is much lower than that of soap. At present 0.18 is probably a better B.O.D. population equivalent value for the partly combined sewage received at the local plant.

Filter Cloths

The wool cloths on the four sludge filters were replaced during 1951 after an average service of more than 1,000 hr. Marked improvement was effected by installing (March, 1951) a booster pump in the water supply line to raise the filter wash water supply pressure from 25 to 100 p.s.i. Better filter washing also reduced the required ferric chloride dosage without decreasing filter yields. Further improvement was effected by substituting air pressure for the ferric chloride pumps, which had always required considerable maintenance.

Table I is a summary of operating data for the fiscal years 1950 and 1951.

* For the last previous extract see *Sewage Works Journal*, **19**, 5, 903 (Sept., 1947).

TABLE I.—Summary of Operating Data for Fiscal Years 1950 and 1951, District of Columbia Sewage Treatment Plant

Item	Average 1950	1951
Sewage flow (m.g.d.)	160.1	160.3
Pop. served (est.)	864,000	819,200
Night soil handled at plant:		
Loads, total	232	227
Gallons, total	159,700	135,883
Grit removed (cu. ft./m.g.)	1.4	1.6
Solids (%)	70.4	70.2
Volatile (%)	19.0	18.5
Suspended solids:		
Raw sewage (p.p.m.)	159	170
Effluent (p.p.m.)	76	77
Reduction (%)	52.2	54.7
5-day B.O.D.:		
Raw sewage (p.p.m.)	132	124
Effluent (p.p.m.)	86	78
Reduction (%)	34.8	37.1
Raw sludge:		
Removed (lb., dry)	110,497	124,133
Solids (%)	6.7	5.9
Vol. sol. (%)	69.4	66.2
Grease	23.8	18.7
Scum:		
Removed (g.p.d.)	9,551	9,119
Solids (%)	15.2	14.2
Volatile (%)	91.4	93.8
Sludge digestion:		
Vol. sol. added daily (lb., dry)	79,117	84,764
Dig. sl. removed (g.p.d.)	121,000	109,000
pH dig. sludge	7.3	7.3
Temp. dig. sludge (°F.)	92	90
Grease in dig. sl. sol. (%)	6.0	5.4
Susp. sol. in sup. (p.p.m.)	13,600	17,450
Sludge gas:		
Total prod. (cu. ft./day)	864,000	794,000
Used (cu. ft./day)	492,000	555,000
Wasted (cu. ft./day)	372,000	239,000
Produced (cu. ft./cap./day)	1.0	1.0
To Naval Res. Lab., total (1,000 cu. ft.)	37,345	47,409
B.t.u., gross (per cu. ft.)	640.3	592.0
B.t.u., net (per cu. ft.)	641.9	592.8
Methane (%)	62.4	34.5
Carbon dioxide (%)	62.3	34.3
Elutriated sludge:		
Solids (%)	8.1	9.0
Vol. sol. (%)	45.1	42.7
Ratio wash water to sl. vol.	1.7	1.4
Alk., dig. sl. (p.p.m.)	2,996	2,788
Alk., elut. sl. (p.p.m.)	839	603
Eff. wash water ratio	2.6	3.6
Elutriate:		
Susp. sol. (p.p.m.)	5,025	2,931
Alkalinity (p.p.m.)	1,700	1,284
5-day B.O.D. (p.p.m.)	905	660
Sludge dewatering:		
Dewatering time, total (days)	219	243
Filter hours, total	3,748.5	4,241.6
Cake produced, total (tons, wet)	28,612	25,023.5
Solids in cake (%)	26.2	28.6
Dry solids in cake, total (tons)	7,501	7,165.3
Yield of solids (lb., dry/sq. ft./hr.)	8.0	6.8
$FeCl_3$ (%)	4.07	3.65
Susp. sol. in filtrate (p.p.m.)	118	166
Operation and maintenance cost, total	$300,235	$302,971

Annual Reports of the Gary (Ind.) Sanitary District Sewage Treatment Plant for the Years 1950 and 1951

By W. W. Mathews, *Superintendent*

Summary of Eleven Years of Operation

The Gary sewage treatment plant went into operation on August 23, 1940, and has operated continuously since that date. In addition to functioning properly and producing a highly polished effluent with low suspended solids and low 5-day B.O.D., several operational problems have been solved to keep maintenance costs low. Economy in operation made it possible to reduce the District tax levy from $0.20 per $100 assessed valuation in 1941 to $0.159 in 1951, a reduction of 20.5 per cent in spite of rising costs during the period.

During the period 1941–1951 removal of suspended solids averaged 97.4 per cent, with the final effluent containing 7.9 p.p.m. Reduction in

TABLE II.—Summary of 1950 and 1951 Operating Data, Gary (Ind.) Sewage Treatment Plant

Item	Average 1950	1951
Rainfall (in.):		
Recorded	35.49	36.18
Normal	33.17	33.17
Population served (estimated)	120,000	122,000
Equivalent population (0.17 lb. B.O.D./cap.)	139,450	163,050
Sewage flow:		
M.g.d.	22.98	23.76
Gal. per capita per day	230	195
Screenings removed (cu. ft. per m.g.)	0.04	0.01
Grit removed (cu. ft. per m.g.)	6.26	6.02
pH:		
Raw	7.0	7.2
Settled	7.1	7.2
Final	7.3	7.3
Suspended solids:		
Raw (lb. per cap. per day)	0.253	0.254
Raw (p.p.m.)	239.0	355.9
Settled (p.p.m.)	102.5	127.0
Final (p.p.m.)	14.7*	11.0
Per cent reduction	93.9*	96.9
B.O.D. (5-day):		
Raw (lb. per cap. per day)	0.219	0.196
Raw (p.p.m.)	123.6	139.7
Settled (p.p.m.)	71.8	81.0
Final (p.p.m.)	13.6*	6.3
Per cent reduction	89.0*	95.5
Activated sludge data:		
Aeration period (hr.)	4.85	4.54
Secondary settling period (hr.)	2.79	2.61
Secondary settling rate (gal./sq. ft./day)	787	838
Mixed liquor susp. sol. (p.p.m.)	1,568	2,272
Sludge index	163.1	105.5
Returned sludge, susp. sol. (p.p.m.)	5,625	8,536
B.O.D. loading (lb./1,000 cu. ft. aerator capacity)	17.5	20.5
B.O.D. removed (lb./1,000 cu. ft. aerator capacity)	15.6	18.9
B.O.D. removed (lb. per 1,000 cu ft. air)	1.248	1.435
Returned sludge (% by volume)	37.69	38.27
Air consumption:		
Million cu. ft. per day	9.728	10.325
Cu. ft. per gal. sewage	0.46	0.46
Cu. ft. per lb. B.O.D. removed	802	691
D.O. at end of aeration (p.p.m.)	4.8	3.5
Blower pressure (p.s.i.)	7.93	7.97

TABLE II.—Continued

Item	Average 1950	1951
Raw sludge:†		
Average daily pumped (gal.)	140,779	169,044
Per cent dry solids (ave.):		
Total	4.0	5.7
Volatile	48.7	45.5
Digested sludge:		
Ave. total solids (%)	7.70	6.46
Ave. volatile solids (%)	39.68	44.63
Dry sludge, 50% moisture (tons)	4,361	5,397
Gas production:		
Cu. ft. per cap. per day	1.46	1.27
Cu. ft. per m.g. sewage	6,036‡	6,500
Cu. ft. per lb. solids added	3.1	2.3
Cu. ft. per lb. volatile solids added	6.4	5.0
Value of gas used ($)	21,911.68	23,133.92
Gas analysis:		
CO_2 (%)	30.0	29.0
CH_4 (%)	61.8	61.4
Hydrogen (%)	5.2	4.8
Nitrogen (%)	3.1	4.8
H_2S raw (grains per 100 cu. ft. gas)	3.0	3.0
H_2S scrubbed (grains per 100 cu. ft. gas)	2.0	2.0
Heat value (B.t.u.):		
Net	624	622
Gross	700	691
Bacterial analysis:		
Raw sewage (total bacteria per ml.)	554,000	406,000
Final effluent (total bacteria per ml.)	88,000	33,000
Raw sewage (B. coli M.P.N. per 100 ml.)	2,040,000	2,392,000
Final effluent (B. coli M.P.N. per 100 ml.)	76,200	41,800
Outlet stream analyses (p.p.m.):		
Upstream ¼ mile:		
D.O.	3.6	4.5
B.O.D.	6.7	4.4
Downstream 2¼ miles:		
D.O.	3.7	4.7
B.O.D.	5.8	4.7
Treatment costs ($):		
Per m.g.	13.15	13.34
Per capita per year	0.92	0.95
Per 1,000 lb. B.O.D. removed	14.33	11.99

* Includes 29 days of primary treatment.
† Includes waste activated sludge solids in secondary digester supernatant liquor.
‡ Based on 100,000 connected population.

B.O.D. averaged 94.0 per cent, with 8.9 p.p.m. in the final effluent.

Electric Power Savings

Gary increased in population from 111,719 in 1940, to 133,911 in 1950. The increase in loading on the treatment plant is larger than the growth in population would indicate. This is because during this period sewage from the steel industry, which formerly discharged to the Grand Calumet River, has been diverted to the main interceptor of the District. Final connection was made as of January 31, 1950. Since that date all sanitary sewage from the various steel subsidiaries has been treated at the District's plant with the exception of Universal Atlas, which has its own treatment works.

In spite of the increased load, power usage has decreased gradually from 871,720 kw.-hr. in 1941, to 564,760 kw.-hr. in 1950, and up to 720,680 kw.-hr. in 1951. The increased power consumption in 1951 was caused by three

factors: first, more sewage was pumped than in any previous year; second, gas production was below normal for the first three months, necessitating the use of more electric power than usual; and third, increased load on the treatment process for the first four months of the year while ammonia still wastes were being treated. Consumption of power per m.g. pumped was 83 in 1951, 77.9 in 1946, and 80.4 in 1949. In 1941, 123 kw.-hr. were required per m.g. pumped. Power saving in dollars, compared to 1941, was $4,712.

Pickle Liquor

Pickle liquor is received from one industry in quantities of 2,000, 3,000, and 6,000 gal. about every third day. Any of these tubs may be dumped on one day and at times any two may be discharged the same day. This waste nominally ranges from 4 to 6 per cent acid. Since the secondary treatment process normally is slightly alkaline this acid waste inhibited biological action. Experiments were carried out through cooperation of the industry. This waste is now handled without any difficulty after neutralization with lime by the industry.

Ammonia Still Wastes

On October 27, 1950, ammonia still wastes were discharged to the main interceptor of the District. These wastes, from the coke plant of the Gary steel works, were discharged uniformally over 24 hr. and initial loading was about 10 per cent of the total load expected. The amount of waste being treated was increased from time to time until March 21, 1951, when the full load was being received, and treatment of all ammonia wastes continued until April 30, 1951, when the experiment was stopped.

The purpose of the experiment was to determine now effectively ammonia still wastes could be treated by the activated sludge process and how efficiently phenol contained in the wastes could be destroyed. Analyses showed that the wastes could be treated and that the phenol was destroyed practically 100 per cent (see THIS JOURNAL, **24**, 2, 164; Feb., 1952).

Table II summarizes the 1950 and 1951 operation data for the plant.

Annual Reports of the Toledo, Ohio, Sewage Treatment Plant for the Years 1950 and 1951

BY A. H. NILES, *Engineer-Superintendent*

1950 Operations

A yearly total of 47.84 in. of precipitation, about 50 per cent greater than normal, increased total pumpage 16.8 per cent over the previous high year (1949) and established a new 24-hr. maximum pumpage record of 125.63 m.g.d. (as compared with the previous record of 98.18 m.g.d., established June 1, 1943). The high flows of low strength established a new low in gas production during the year, with a consequent new low in savings due to gas engine use.

In addition, the excess rainfall caused high ground-water conditions, resulting in heavy infiltration, soil collapse, sewer cave-ins, and overloading of the digester mechanisms with grit and other inert soil solids. These problems only served to aggravate the overloaded condition of the plant, particularly when delays were encountered in securing suitable pumps for emptying silt-clogged digesters.

A further result of the low solids content of the sewage was a reduction in the amount of fertilizer made during the year. This will be reflected in reduced income from this source in 1951.

Operational costs of automotive equipment operated by the Division of Sewage Disposal during the year were as follows:

Make and Type	Year Made	Miles Driven			Cost ($)		
		Total	1951	Per Gal. Gas	Gas, etc.	Maint.	Per Mile
Federal truck	1938	47,891	1,709	5.3	87.42	105.02	0.112
Chevrolet truck	1939	60,032	3,680	4.9	193.08	257.26	0.122
Ford tudor	1947	32,253	10,347	14.4	183.78	99.74	0.027
Dodge panel del.	1947	10,286	3,353	11.7	73.56	57.83	0.039
Chevrolet coach	1948	17,822	8,984	16.7	151.26	83.11	0.026
Studebaker truck	1949	5,171	2,932	5.2	141.90	35.98	0.06
Chevrolet coach	1949	12,355	8,395	16.0	133.98	49.98	0.022

1951 Operations

The 1951 precipitation was only 13 per cent above normal, totaling 36.18 in., or 11.16 in. less than 1950. As a result, both the total pumpage and the daily maximum were less than in 1950,

TABLE III.—Summary of Operation of the Toledo (Ohio) Sewage Treatment Plant for 1950 and 1951

Item	Average 1950	1951
Rainfall (in.)	47.84	36.18
Design flow (m.g.d.):		
Mean D.W.F.	80.0	80.0
Max. D.W.F.	140.0	140.0
Raw sewage flow (m.g.d.):		
Minimum	34.10	32.80
Maximum	125.63	88.84
Average	54.30	53.90
Screenings (cu. yd. per month)	237	178
Grit removed (cu. yd. per month)	79	34
Suspended solids (p.p.m.):		
Raw sewage	163	174
Plant effluent	86	91
Per cent removal	45.9	47.7
B.O.D. (p.p.m.):		
Raw sewage	169	183
Plant effluent	122	128
Per cent removal	27.5	30.0
Volatile solids (%):		
Raw sludge	61.2	65.9
Digested sludge	39.4	40.6
Digested sludge (cu. yd.):		
To marsh	37,085	20,150
To drying beds	7,060	8,585
Dry sludge pulverized for fertilizer (tons)	687	719
Fertilizer sold (tons)	1,083	706
Total sales ($)	13,234	8,657
Bay View pumping station costs ($ per m.g.):		
Purchased power	0.70	0.64
Supplies	0.41	0.34
Supervisions and labor	3.36	3.84
Total	4.51	4.82
Sewage works cost ($ per m.g.):		
Power	0.006	0.007
Supplies	1.04	1.33
Supervision and labor	6.21	6.84
Total	7.26	8.18
Gas engine economy ($):		
Pumping cost if power purchased	29,525	29,525
Actual pumping cost	13,359	13,359
Gas engine saving	16,166	16,166

but were still high by comparison with former years.

General estimates by wholesale distributors indicate a 50 per cent increase in detergent use in Toledo in the last three years, which may explain some of the decrease in efficiency of primary sedimentation.

Recommendations

Operating deficits have increased to such an extent that rate increases on sewer rentals are urgently needed. So, also is addition of secondary treatment facilities to the plant, which is seriously overloaded.

Operating data for 1950 and 1951 are summarized in Table III.

TIPS AND QUIPS

Quarter Century Operators' Club

Were you in direct charge of the operation of a sewage treatment plant at or before the time the Federation was founded, 25 years ago? If you were, and now belong to one of the Member Associations of the Federation, you are eligible for membership in the Quarter Century Operators' Club.

Application for membership should be addressed to:

Frank Woodbury Jones
1140 Leader Building
Cleveland, Ohio

setting forth your name, address, and present occupation; the dates between which you were in responsible charge of operation of a municipal sewage treatment plant on a full-time basis; the location and type of plant; your present Member Association affiliation; and at least three references, preferably members of the Club.

For recognition as a "25'er" at the Federation's 25th Anniversary Meeting, applications should be submitted without delay.

"Raincoat" for Masonry Walls

A new invisible "raincoat" for masonry walls is claimed to make all types of above-grade porous masonry water repellent immediately after drying. Added claims are that the product is completely invisible, will not discolor, will not wear away, sheds dirt, controls efflorescence, and one application will stop driving rain.

Known as Hydrocide SX (colorless), it penetrates to make the masonry itself water repellent. Detailed information can be secured from Building Products Div., L. Sonneborn Sons, Inc., 80 8th Avenue, New York 11, N. Y.

Toward Better Sludge

In an attempt to maintain a higher temperature in the Marion, Ind., sewage treatment plant digesters, former superintendent D. P. Backmeyer tried using digester liquor to grind and sluice garbage. In this plant the ground garbage is added directly to the digesters, making the heat conservation effort extremely worthwhile.

Another operating economy resulted from the use in this plant of activated sludge as the sluicing liquid during the warm summer months, a practice that also helped cut down the odor problem raised by digester liquor use.

Sampling of the digesters, a fertile source of odors in the digester control area, also has been made aesthetically much more pleasant by the installation of a motor-driven exhaust fan connected to a new hood over the sampling sink.

Even the final product came in for its share of attention. The digested

sludge, sold in liquid form and distributed directly on the fields from tank trucks, has been made a balanced fertilizer. This phase is accomplished by adding the required amount of potash to each load as the tank is being filled.

Ice Control

Ice formation on secondary clarifier drive chains and sprokets, often sufficient to cause possible damage to those parts, used to be one of the winter operational problems at the Belvidere, Ill., sewage treatment plant. In his 1951 Annual Report, however, Superintendent F. E. Peterson notes a positive but simple and economical solution. He simply installed an infra-red heat lamp under the hood-guard and connected it to an outside socket of the lighting circuit. Result: no ice problem.

Do's and Don'ts in Belt Care

V-Belts

1. Be sure drive and driven shafts are in alignment.
2. Keep belts tight. Every drive should have adjustment to take up for stretch as the belts age.
3. If temperature is above 120° to 130° F., use a special heat-resisting belt, unless you're willing to accept shortened life.
4. If oil, dilute acids, or unusual atmospheres surround the belt, use special oil-resisting belts.
5. Use matched sets of belts for longer life. Replace the set, not a single belt.
6. Don't pry new belts onto a sheave. The bar may rupture cord construction.
7. Don't use belt dressing.
8. Store spare belts in a cool, dry place protected from light and heat.
9. Be sure the drive is not overloaded and that sheave diameters are not too small.
10. Use recommended peripheral speeds.
11. Don't allow belts to bottom in grooves. This causes slippage and life-killing heat.
12. Keep groove sidewalls smooth and edges rounded.
13. If a V-belt drive is to be out of use, remove the belts and store in a cool, dry place. Coat sheaves with grease, but remember to clean sheaves thoroughly before belts are replaced.

Flat Belts

1. Don't run belts exposed to weather if unavoidable.
2. Maintain proper tension. Run the belt as slack as possible while avoiding slip. Run, if possible, with the slack side on top.
3. Use a tension-type motor base on short-center drives.
4. Don't use undersized pulleys.
5. Keep belts clean and avoid oil or water soaking.
6. Dress leather belts regularly with a good belt dressing every 6 months for a year, then every 3 months. Don't use sticky dressings.
7. Run leather belts with the hair or grain side to the pulleys.
8. Use endless belts when possible.
9. Run a belt so that feather edges of laps on the pulley side point away from the pulley as they approach its face.
10. Be sure a belt is square and lined up before splicing.
11. When using belt lacing or other fasteners, cut belt ends square and be sure they line up.
12. Renew worn fasteners before they cause breakage or tearing.
13. Re-cement feather edges and laps whenever they show openings.
14. If the belt doesn't run properly, remove the cause of trouble. Don't run the belt edge against any stationary object.
15. Avoid shifters that do not throw the belt entirely on or off the loose

pulley. Otherwise one side of the belt will be stretched.

16. Don't run belts on flat-faced pulleys except on shifter drives.

17. Avoid idlers if possible; they put a reverse bend in the belt. If you must use them, use an approved type, properly installed.

18. Don't overload any belt and expect proper service thereafter.

19. On rubber belts, use an approved dressing to soften the surface and make it grip.

20. Keep pulleys clean. Lumps there cause belt blisters and ply separation.

21. Avoid slippage, shown by highly polished pulley surfaces and glazed belt surfaces.

22. Align flanged pulleys carefully to avoid flange rubbing on the belt edge.

23. Pulleys with excessive crown will cause fastener failure.

24. Run folded rubber or fabric belts with seam on the outside, except where pulley crown is excessive.

Conveyor Belts

1. If the belt runs crooked or out of line, it may be improperly trained. Straighten it up, or excessive wear is certain.

2. If one part of the belt runs out of line, the belt is crooked. If this part is at the joint, the splice is not square.

3. If the belt runs out of line at a certain point or over certain idlers, the second or third idler before the run-out point is usually at fault.

4. If the belt rides up on one side, it is not being loaded equally across. Reset the loading chute.

5. Avoid stuck idlers; they deflect the belt, as do idlers out of square.

6. Keep tail and head pulleys in exact alignment.

7. If wind, or change in type of material carried, causes trouble, use self-aligning idlers.

8. Don't use skirt boards, pilot boards, or guides that touch the belt. They hasten edge wear.

9. Use trippers with pulleys as large as possible and keep the belt from touching the tripper frame.

10. Keep belt tension as low as possible.

11. Don't drop material on a belt—slide it on.

12. Don't let the edge of the loading chute touch a belt.

13. Where mixed material is carried, use a coarse screen at the end of the lip, so that fines fall through to form a cushion for the lumps.

14. Don't use a discharge scraper. If cleaning is necessary, use revolving brushes.

15. Pulleys should be 2 in. wider than the belt; drive pulleys should have 3 in. of diameter per belt ply.

16. Be sure return idlers are properly spaced.

17. Maintain a rigid and regular inspection, lubrication, and maintenance schedule. Keep oil and caking off.

18. Don't stop the belt under load, if possible.

19. If a replaced belt stretched excessively, use more plies in the new one.

20. If top or bottom cover wore out, better quality or thicker covers are needed.

21. If plies separated, a higher-quality friction is needed.

Hooked!

According to the May, 1952 issue of *The Digester*, Illinois Health Department quarterly for sewage plant operators, a sportsmen's club in the East actively backed a bill in their state legislature that would have made it illegal to throw into a stream anything that would kill fish. Imagine the consternation and confusion when it was learned that even fishhooks would be classified as illegal under the act!

Does Septic Sludge Form Digester Scum?

Introduction of septic sludge into a digester will cause formation of a scum

blanket in the digester. At least that is the conclusion drawn by Carroll H. Coberly, consulting engineer, Denver, Colo. The experiences leading him to this conclusion are as follows:

1. In the Estes Park plant the digester was seeded with a very septic sludge. A scum blanket formed that was close to 7 ft. thick and so hard that a 2 by 4 could not be pushed down through it. The sewers feeding this plant were mostly on a steep grade with no low spots in the line. It was almost a year before this digester went into successful operation, and since that time there has been no difficulty with a scum blanket.

2. The next plant was the Fort Logan plant. The sewers in the old part of the post were very flat. When the sewage was turned into the new plant the odor was terrible. The sewers were finally rodded and flushed out and the odor was abated. Right at the beginning a scum blanket formed on the digester, but after the sewers were cleaned out there was no more trouble with a scum blanket.

3. In Aurora there are two Imhoff tanks. The sewers in Aurora are all on a good grade with nothing less than a minimum grade of 0.4 per cent for an 8-in. sewer. There has been no trouble with scum forming on the gas vents of the tanks.

4. At Simla another Imhoff tank was built. The sewers in this district are all steep, with a minimum of 0.4 per cent grade on an 8-in. sewer. Here, also, there has been no trouble with scum forming.

5. In Wheatridge the sewers are all above minimum grade and there has never been more than ½ in. of scum on the digester at any time. Of course, in this plant the sludge is removed from the clarifier every 15 min. so that it is impossible to have septic sludge form in the clarifier at any time.

Mr. Coberly reasons that with sewers on greater-than-minimum grades and with proper clarifier operation there is little chance of septic sludge being pumped to the digester. On the other hand, the gas on septic sludge particles buoys the solids to the top of the digester, preventing proper seeding of the sludge and permanently trapping some of the sludge in the scum blanket.

If any others have had experience with scum formation (or lack of it) in digesters subjected to septic sludge loading, we would be glad to hear of it and pass on to others any worthwhile practical observations. Just send your comments to the "Corner."

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pH Control Solves Bleachery Waste Problem

Acid and alkaline wastes at a well-known New England textile finishing plant are effectively neutralized under pH control, furnishing conditions for optimum biological activity and efficient waste disposal.

The separate wastes are collected in equalization tanks. To create a neutral pH condition in the underground mixing basin, a closely regulated flow of acid waste is mixed with the alkali waste. The resulting effluent is then further treated on trickling filters.

A recording controller located in the pump house controls the pH. A small circulating pump supplies a continuous sample to a flow-type electrode. As the measured pH changes, the controller operates a 3-in. rubber-lined valve in the acid line to maintain the desired condition.

Since the efficiency of this waste disposal system depends on an unchanging neutral pH, control is automatically maintained within the desired tolerance limits despite variations in acid and alkaline wastes concentration and rates of flow. Because more acid wastes are produced at times than can be handled with the plant's alkali wastes, alkali make-up tanks provided

are equipped with flow controls operated by liquid levels in the collecting tanks.

Pipe "Bloodhound"

Now just a minute! We're not claiming that it works or doesn't work. All we're doing is reporting what actually happened. And if the truth seems stranger than fiction . . . but let's start at the beginning.

It all began a few weeks ago when an engineer member visited the Federation office and told what seemed to be one of the usual "water witching" stories. Only this one involved a couple of lengths of clothes-hanger wire and concerned locating pipes—not just metal pipes, but all kinds, including sewers and drains composed of concrete, tile, and other materials.

We, of course, listened with a raised eyebrow, figuring that somewhere there was a simple explanation for the whole thing. In fact, we had in mind the M-Scope method of finding lost sewers and drains as used by E. T. Cranch at New Rochelle, N. Y. (see *Sewage Works Journal*, **17**, 2, 199; Mar., 1945). Our informant insisted, however, that no such apparatus was involved. Further, that the wires were cut and bent (Figure 1) from clothes hangers while he watched, and that he himself, skeptic that he was, had used them with immediate success on drains whose locations in a strange area were unknown to him before he used the wires.

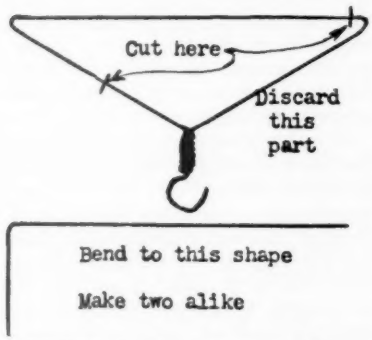

FIGURE 1.—How wire coat hangers are cut and bent to make simple pipe locater.

Well, the engineer members of the Federation staff had to try the scheme themselves—under cover first, of course. But successful use in private on known pipes engendered a curiosity as to how it worked on pipes unknown to them. This involved using the device in the open, with the usual neighborly comments about treasure hunters, crackpots, etc. The skepticism was generally dispelled, however, by the apparent results, not only on water and gas pipes, but also on sanitary sewers and storm drains.

Up to this point the wires had been held loosely in the bare fists, long ends parallel, about 18 in. apart, and pointing ahead as the user walked slowly over the area. When over a pipe the wires are supposed to swing slowly through a 90° angle until they form a straight line, supposedly indicating the direction of the pipe.

Soon, however, came support for the idea in the form of a reference to the "Ware Dowser" (*Wastes Eng.*, **23**, 6, 313; June, 1952). In this case the wires are described as of bronze (3/16-in. welding rod) and the short legs bear in short pieces of copper tubing which act as handles.

Well, there it is. As previously noted, we're not guaranteeing anything. If you're interested, why not try the clothes-hanger "pipe sniffer" for yourself? But don't say we didn't warn you about the neighbors' remarks!

Editorial

A QUARTER-CENTURY OF PROGRESS

If only for the record, it is fitting that the development and accomplishments of the Federation be reviewed on the occasion of its Twenty-fifth Anniversary. This brief commentary can of necessity merely spotlight the most significant milestones.

It seems that the idea of a national sewage works organization first gleamed in the eyes of the late George W. Fuller, who gathered a few leading sanitary engineers for a preliminary discussion in the Spring of 1927. With the aid of Charles A. Emerson and the late Harrison P. Eddy, Mr. Fuller brought about creation of the Committee of One Hundred in Chicago on June 10, 1927, and the efforts of that body culminated in the organization of the Federation of Sewage Works Associations at Trenton, N. J., on March 23, 1928.

Following is a chronological log of key physical developments since:

1928—Original secretarial headquarters established in Harrisburg, Pa., business management assumed by The Chemical Foundation in New York City, and editorial office in Chicago. First issue of SEWAGE WORKS JOURNAL—then a quarterly—distributed in October.

1932—Journal publication increased from quarterly to bi-monthly.

1938—Tenth Anniversary Book, "Modern Sewage Disposal," published.

1940—First national technical convention held at Chicago.

1941—Reorganization and expansion undertaken with centralization of administration and business management under a part-time Secretary, with headquarters at Urbana, Ill. Program of technical and professional awards initiated. Committee structure strengthened. Federation incorporated.

1944—Headquarters office established in Champaign, Ill., with full-time staff handling all administrative, business management and editorial functions. First Manual of Practice published and distributed.

1950—Emphasis given to interest in industrial waste problems by adoption of name change to Federation of Sewage and Industrial Wastes Associations, and by change of Journal name to SEWAGE AND INDUSTRIAL WASTES. Publication of Journal increased from bi-monthly to monthly.

Each of the above moves was accomplished successfully by meticulous planning and enthusiastic execution. Thus was a new technical society born and nurtured to healthy maturity. The growth of the Federation bespeaks the success of the venture, for the eight charter Member Associations with a total membership of 273 are now increased to 38 affiliated associations having an aggregate membership of 5,500! Prospects of substantial further growth are most promising.

In accomplishment, the Federation has moved toward its stated objectives in proud fashion. Its Journal is acknowledged around the world as the foremost medium of technical information exchange in water-borne waste disposal and water pollution control. Six noteworthy Manuals of Practice have been produced, and many others are in preparation. The annual meetings of the Federation have gained wide favor for their high technical and professional caliber, and their friendly atmosphere. Committee contributions are too numerous to enumerate here, and they include many activities undertaken jointly with other national organiza-

tions of overlapping interests. The voice of the Federation is now strong enough to be heard in national affairs pertinent to its aims, such as legislation and emergency regulations that concern operations in the field. The headquarters office, though still modest in its facilities, is rendering a multitude of services not readily available elsewhere. Financially, the Federation is now a going concern with sufficient resources to carry through any serious emergency—a far cry from the early days of gracious subsidization by The Chemical Foundation.

Especially satisfying has been the relationship of the Federation with its Member Associations outside the U. S., of which there are now six. A pattern of cordial international cooperation has been built up here that might be followed to great advantage by national governments.

At least general mention must be made of the individuals and groups who have brought the Federation to its present strong position. All of the individuals cannot be named here, but such men as Charles A. Emerson (Board chairman from 1928 to 1941), H. E. Moses (secretary from 1928 to 1941), F. W. Mohlman (editor from 1928 to 1943), Willem Rudolfs (original contact with Chemical Foundation), the late W. W. Buffum (business manager of Chemical Foundation), William J. Orchard (financial advisor), Harold W. Streeter, Langdon Pearse, and W. D. Hatfield must be placed at the top of the list. They and many others have contributed time and effort far beyond the degree that could be justified by professional duty and responsibility alone.

In addition, the early support given by The Chemical Foundation must be acknowledged, as well as that extended by the Water and Sewage Works Manufacturers Association since 1941. The Member Associations and their leadership are deserving of great credit, for it is the strength and vigor of these constituents that has given stature to the Federation. And it must be noted that the expansion of the Journal through the years has been possible only because of the advertising support that it has enjoyed, for which appreciation is due our advertisers.

All this is background for the Silver Anniversary Meeting at New York City on October 6–9. It is a record worthy of celebration!

W. H. W.

MAKE YOUR HOTEL RESERVATIONS FOR THE FSIWA SILVER ANNIVERSARY MEETING

The Hotel Statler at New York City will be the headquarters for the Federation's Twenty-Fifth Annual Meeting, to be held in October. An outstanding Silver Anniversary program is being planned for the four-day meeting.

Requests for room reservations should be addressed directly to the hotel. It should be noted that the technical program will open on Monday morning, October 6, and will close at noon on Thursday, October 9. However, the usual inspection trip will this year be scheduled for the afternoon of October 9, after the close of the meeting.

WRITE NOW FOR YOUR RESERVATIONS!

Federation Affairs

SILVER ANNIVERSARY MEETING PREVIEW

Hotel Statler, New York, N. Y., October 6–9, 1952

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IN CONJUNCTION WITH
THE NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

*

THE OFFICIAL PROGRAM

SUNDAY, OCTOBER 5

Afternoon

Early Registration—Mezzanine.
Inspection of Exhibits—Georgian Room; Parlors 1 and 2.

MONDAY, OCTOBER 6

Morning

Registration—Ballroom Foyer.
Inspection of Exhibits—Georgian Room; Parlors 1 and 2.
Twenty-Fifth Annual Meeting Called to Order—Ballroom.
President Earnest Boyce
Reports of FSIWA Officers
Sewage Disposal Problems of the World's Largest City
R. H. Gould, Director, Division of Engineering, Dept. of Public Works, New York, N. Y.

Afternoon

Detergent Compounds, Their Composition and Behavior
Lawrence Flett and L. H. Hoyt, National Analine Division, Allied Chemical and Dye Corp., New York, N. Y.
Discussion: Willem Rudolfs, Chief, Dept. of Sanitation, New Jersey Agricultural Experiment Station, New Brunswick, N. J.
Operating Experiences with Detergents at Washington, D. C.
Ralph E. Fuhrman, Superintendent, District of Columbia Sewage Treatment Plant, Washington, D. C.
Discussion: Samuel A. Greeley, Consulting Engineer, Chicago, Ill.
The Action of Detergents in Sewage Treatment—A Study by Industry
W. R. Gowdy, Chemical Division, The Proctor and Gamble Company, Cincinnati, Ohio.
Discussion: W. N. Wells, Superintendent, Sewage Treatment Plant, San Antonio, Tex.
Effect of Detergents on Sewage Microorganisms
Raymond Manganelli and Edwin S. Crosby, Dept. of Sanitation, Rutgers University, New Brunswick, N. J.
Discussion: W. L. Mallmann, Professor of Bacteriology and Public Health, Michigan State College, East Lansing, Mich.

Evening

FAMILY NIGHT ENTERTAINMENT—Ballroom.

TUESDAY, OCTOBER 7

Morning

Sewage Works Management

Henry J. Graeser, Assistant Superintendent, Dallas Water Dept., Dallas, Tex.

Discussion: V. P. Enloe, Superintendent, Clayton Sewage Treatment Plant, Atlanta, Ga.

Rehabilitation of the Schenectady Sewage Treatment Plant

Edward S. Ordway, Engineer, Havens and Emerson, New York, N. Y.

Discussion: Morris M. Cohn, City Manager, Schenectady, N. Y.

Electric Power System Practices for Sewage Plants

M. C. Boggis, Application Engineer, General Electric Co., Schenectady, N. Y.

Discussion: R. R. Kennedy, Consulting Engineer, San Francisco, Calif.

Noon

SILVER ANNIVERSARY LUNCHEON—Ballroom.

The Federation from 1927 to 1952

Charles A. Emerson, Consulting Engineer, New York, N. Y., and first President of the Federation.

The Next Quarter Century and the Federation

Abel Wolman, Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md., and first Vice-President of the Federation.

Afternoon

Operating and Economic Factors in a Packinghouse Waste Problem

H. O. Halvorson, Professor of Bacteriology, University of Illinois, Urbana, Ill.

Discussion: M. D. Sanders, Research Chemist, Swift and Co., Chicago, Ill.

Milk and Dairy Wastes: Treatment and Disposal

S. I. Zack, Sanitary Engineer, Gannett Fleming Corddry and Carpenter, Inc., Harrisburg, Pa.

Discussion: L. F. Warrick, Chief, Technical Service Branch, Division of Water Pollution Control, USPHS, Washington, D. C.

Waste Recovery and Treatment in Viscose, Rayon, and Film Manufacture

H. L. Jacobs, Engineering Service Division, E. I. duPont de Nemours and Company, Inc., Wilmington, Del.

Discussion: Charles E. Renn, Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md.

Chemical Wastes Disposal by Pratt and Whitney Aircraft

Allen J. Burdoin, Metcalf and Eddy, Boston, Mass.

Discussion: Guy E. Griffin, Water Supply Engineer, American Cyanamid Co., New York, N. Y.

WEDNESDAY, OCTOBER 8

Morning

Biological Factors in Stream Sanitation
Ruth Patrick, Curator of Limnology, Academy of Natural Sciences, Philadelphia, Pa.
Discussion: A. R. Gaufin, Biologist, Stream Sanitation and Sewage Treatment Unit, Biology Section, USPHS, Cincinnati, Ohio.

Simplified Determination of B.O.D. Curve Characteristics
Harold E. Orford, Associate Professor of Civil Engineering, and W. T. Ingram, Associate Professor of Public Health Engineering, New York University, New York, N. Y.
Discussion: Harold A. Thomas, Jr., Associate Professor of Sanitary Engineering, Harvard University, Cambridge, Mass.

Bactericidal Efficiency of Sewage Chlorination
Seth G. Hess, Director and Chief Engineer; Alex N. Diachishin, Assistant Engineer; and Paul DeFalco, Jr., Assistant Engineer, Interstate Sanitation Commission, New York, N. Y.
Discussion: W. W. Sanderson, Chemist, Division of Laboratories, State Health Dept., Albany, N. Y.

Photosynthetic Oxygenation in Sewage Treatment
Harold B. Gotaas, Professor of Sanitary Engineering, University of California, Berkeley, Calif.

Afternoon

INDUSTRIAL WASTES FORUM
R. W. Hess, Leader
Flotation
Skimming
Subsurface Disposal
Lagooning with Sodium Nitrate
Anaerobic Digestion
High-Rate Filtration

Evening

SILVER ANNIVERSARY DINNER AND DANCE—Ballroom.

THURSDAY, OCTOBER 9

Morning

SEWAGE OPERATORS' FORUM
J. Henry L. Giles, Leader
Pumps
The Sewage Plant Laboratory
Personnel Recruitment and Training
Sludge Recovery and Utilization
Aerobic Treatment Units
Sludge Digestion

Afternoon

Inspection Trip
New York City sewage treatment facilities, particularly the Owls Head sewage treatment plant.

TECHNICAL PROGRAM COMMENTS

The technical program developed by the Program Committee, under the chairmanship of F. W. Gilcreas, is designed to have such wide diversity as to appeal to all Federation members.

In compliance with numerous requests of recent years, the forum sessions for operators and industrial wastes personnel will be held at different times. The Operators' Forum will occupy its usual Thursday morning period, but the Industrial Wastes Forum has been shifted to Wednesday afternoon to give added emphasis to both popular features.

SOCIAL FUNCTIONS

An informal Family Night Entertainment on Monday evening will provide fun for all and a good chance to greet old friends and meet new ones. A program of professional vaudeville talent will be featured.

The Silver Anniversary Luncheon, to be held Tuesday noon, will focus attention on the quarter century of growth and progress of the Federation completed this year and the outlook for the next quarter century. The original officers and Board of Control members will conduct the luncheon program, as well as being the honored guests. Featured speakers will be C. A. Emerson, Consulting Engineer, New York City, and first Chairman of the Federation; and Abel Wolman, Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md., and first Vice-Chairman of the Federation. Mr. Emerson's subject will be "The Federation from 1927 to 1952"; Professor Wolman's, "The Federation and the Future."

There will be no programmed entertainment on Tuesday evening, allowing for dining and playing according to individual choice. Theater information has been furnished in the advance program sent to all members in mid-July.

The always popular Annual Dinner and Dance on Wednesday evening will climax the meeting. Featured at this function are the presentations of annual Federation awards and honors. There will also be music and entertainment, with dancing to an excellent orchestra. Dress will be optional.

LADIES' ENTERTAINMENT

Special entertainment for the ladies will emphasize the many sightseeing features of the world's largest city and the home city of the United Nations. These events will be in addition to those scheduled for Monday and Wednesday evenings, as outlined under "Social Functions."

Monday will be a busy day, starting with a trip to the United Nations Buildings in the morning. Included will be a visit to one of the Council sessions and an optional Dutch treat luncheon in the dining room of the U. N. Building. The afternoon attraction is to be a Tea and Fashion Show in the Charleston Garden Restaurant of B. Altman and Co., a leading New York department store. This latter function is graciously being sponsored by the New York Sewage and Industrial Wastes Association, hosts to the Federation meeting.

On Tuesday the ladies will take a sightseeing trip around Manhattan Island by boat. This is a unique and delightful way to see bustling New York City and its many famous sightseeing landmarks without getting involved in the bustle.

Wednesday and Thursday are set aside for optional tours. The selection of low-cost guided trips will include Radio City, the Hayden Planetarium, the

Cloisters, the Metropolitan Art Museum, the Museum of Modern Art, and possibly an ocean liner in dock.

INSPECTION TRIP

The inspection trip on Thursday afternoon will highlight a visit to the Owls Head Pollution Control Project. In this new 160-m.g.d. sewage treatment plant are incorporated all the latest design and operational advances resulting from experience at the other New York City plants. In addition, the housing of aeration and settling basins, with ventilation of the structure providing for ozonation of the gases before being exhausted to the atmosphere, is a feature worthy of considerable attention, as are also the many other innovations in the plant's design.

Special attention is invited to the fact that the inspection trip this year is scheduled for Thursday afternoon, after the official closing of the meeting. However, most of those attending the meeting will want to stay to see at first hand the latest developments in the sewage treatment works program of the world's largest city and the country's most important port.

EXHIBITS

The display of improved and new equipment and supplies planned for the Silver Anniversary Meeting by the Water and Sewage Works Manufacturers' Association promises to be the largest and best of many such exhibits. Some 38 manufacturers and suppliers had been allocated all available exhibit space by early August. Viewers of the exhibit will be able not only to see the modern equipment of the sewage and industrial wastes treatment field, but also will be able to get first-hand technical data from informed company representatives.

The following companies have scheduled representation in the exhibit:

American City Magazine
American Well Works
Builders-Providence, Inc.
Carter Company, Ralph B.
Chain Belt Company
Chicago Pump Company
Combustion Engineering-Superheater, Inc.
Dorr Company, Inc.
Fairbanks, Morse & Company
Fischer & Porter Company
Flexible Sewer-Rod Equipment Company
General Laboratory Supply Company
Hardinge Company, Inc.
Inertol Company, Inc.
Infilco, Inc.
Jeffrey Manufacturing Company
Johns-Manville Sales Corp.
Komline-Sanderson Engineering Corp.
Koppers Company, Inc.
Lakeside Engineering Corp.
Lignum-Vitae Products Corp.
Limestone Products Corp. of America
Link-Belt Company
Lock Joint Pipe Company
Nichols Engineering & Research Corp.
Omega Machine Company
Pacific Flush-Tank Company
Preload Company, Inc.
Public Works Magazine
Simplex Valve & Meter Company
Vapor Recovery Systems Company
Walker Process Equipment, Inc.
Wallace & Tiernan Company, Inc.
Wastes Engineering
Water & Sewage Works
Westinghouse Electric Corp.
Worthington Corporation
Yeomans Brothers Company

REGISTRATION INFORMATION

As tentatively established, a fee of $11.00 will cover the men's registration, technical session privileges, the Family Night Entertainment on Monday evening, and the Dinner and Dance on Wednesday. Tickets for the Silver Anniversary Luncheon of the Federation on Tuesday will be $3.50, and for the Thursday Inspection Trip will be $1.00.

In separate tickets, the registration fee (required for admission badge to the technical sessions) will be $5.00, and the Wednesday Dinner and Dance $6.00.

Ladies' registration at $11.00 will include the Monday evening entertainment, the Wednesday Dinner and Dance, and all special events for the ladies.

Early registration will be desirable to avoid the Monday morning rush. To facilitate this, early arrivals will have an opportunity to register on Sunday afternoon, October 5, from 2:00 to 5:00 PM, when the registration desk will be open on the Mezzanine Floor. The Manufacturers' Exhibits also will be open at that time.

HOTEL ARRANGEMENTS

A liberal allocation of rooms has been reserved by the Hotel Statler for Federation members and guests. Reservations should be placed early, however, as the commitment of rooms expires on September 21.

Requests for reservations may be made on the cards sent in July to all JOURNAL subscribers with the advance notice of the meeting, or by letter directly to the Hotel Statler, New York, N. Y., stating that the accommodations are desired in connection with the Federation meeting.

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, under the chairmanship of George E. Symons, Consultant and Technical Editor, Larchmont, N. Y., is composed of the chairmen of the following sub-committees:

Registration Committee: C. R. Velzy, chairman; R. D. Nickerson, W. T. Ingram, J. J. Baffa, and H. P. Orland.

Finance Committee: T. T. Quigley, chairman; J. C. Brigham, R. C. Sweeney, and J. Porter.

Inspection Trip Committee: W. A. O'Leary, chairman; N. I. Kass, S. W. Steffensen, and W. L. Sylvester.

Entertainment Committee: J. J. Horgan, chairman; J. G. Stewart, C. K. Perkins, J. D. Bowe, and A. O. Hopper.

Ladies Entertainment Committee: Mrs. Karl Mann, chairman; Mrs. G. E. Symons, Mrs. R. Hazen, Mrs. C. R. Velzy, Mrs. H. A. Faber, Mrs. S. G. Hess, Mrs. M. M. Hirsh, Mrs. J. J. Horgan, Mrs. H. S. Sutton, Mrs. E. M. Jones, Mrs. A. L. Morris, Mrs. R. D. Nickerson, Mrs. W. A. O'Leary, Mrs. R. F. Orth, and Mrs. T. T. Quigley.

Local Host Committee: S. G. Hess, chairman; T. M. Riddick, A. J. Fischer, J. M. Brown, Jr., F. C. Roe, D. M. Ditmars, and A. N. Diachishin.

Hotel Arrangements Committee: H. A. Faber, chairman.

Reviews and Abstracts*

Summary Report on Water Pollution; New England Drainage Basins. U. S. Pub. Health Service Publ. No. 88 (1951).

In the various drainage areas of the region covered by this report, sewage and waste treatment projects estimated to cost more than $250,000,000 are recommended at 1,440 municipal and industrial locations in 6 states. Initial cost of required municipal collection and treatment facilities is estimated at $197,700,000, with approximately $52,300,000 needed for initial cost of industrial waste treatment installations. The latter figure is exclusive of industrial wastes now discharged to municipal sewer systems and all cost figures exclude the pollution sources for which project requirements are undetermined.

Of the 1,440 sewage and waste treatment projects needed in the region, 692 are for municipalities and 748 are for separate industries. Municipalities need 593 new treatment plants, additions or enlargements to 84, and replacement of 15 plants. Industry needs 671 new plants, additions or enlargements at 68, and 8 replacements.

No projects are needed at 228 municipal and 96 industrial locations, but project needs are undetermined for 96 municipalities and 303 industries. H. P. Orland

Summary Report on Water Pollution; Lake Erie Drainage Basin. U. S. Pub. Health Service Publ. No. 119 (1951).

Wastes treatment facilities estimated to cost between $50,000,000 and $70,000,000 are needed at 142 municipal and 129 industrial locations in the Lake Erie drainage basin, covering areas in Indiana, Michigan, Ohio, and Pennsylvania draining into Lake Erie between the Michigan-Ohio and Pennsylvania-New York borders.

Wastes are discharged from 206 centers of population and from 187 industries through sewers not connected to municipal systems. Treatment facilities are provided for 99 of the public systems and 70 of the industrial outlets. Municipalities need 91 new treatment plants, 41 enlargements or additions to plants, and 10 replacements of plants. Industries need 96 new treatment plants, additions or enlargements to 22 plants, and 11 replacements of plants. No projects are required for 61 municipalities and 35 industries. Project needs are undetermined for 3 municipalities and 23 industries.

H. P. Orland

Summary Report on Water Pollution; Ohio River Drainage Basin. U. S. Pub. Health Service Publ. No. 136 (1951).

The cost of completing the needed pollution abatement works in the Ohio River drainage basin is estimated as being between $350,000,000 and $400,000,000, plus an unknown additional amount to abate pollution due to inorganic wastes and acid mine drainage.

Treatment facilities are needed at 1,082 municipalities and 680 industrial plants in at least parts of 11 states. Polluting wastes are discharged by 2,104 municipalities and 1,264 industries not connected to municipal sewer systems. Treatment facilities of some type are provided for 566 municipal and 451 industrial pollution sources. Municipal pollution sources require 911 new treatment plants, enlargements and additions to 132 plants, and replacement of 39 plants. Industrial waste sources require 539 new treatment plants, enlargements and additions to 108 plants, and replacement of 33 plants. No projects are required at 327 municipalities and 231 industries. Project needs are undetermined for 695 municipalities and 353 industries. During 1946–9, 33 municipal and 160 industrial waste treatment plants were constructed. In addition, corrective measures have been initiated for 495 municipal and 212 industrial sources of pollution. H. P. Orland

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

Summary Report on Water Pollution; North Atlantic Drainage Basins. U. S. Pub. Health Service Publ. No. 111 (1951).

A minimum of $1,000,000,000 is estimated to be the cost of needed pollution abatement works in the North Atlantic drainage basins area. Treatment facilities are required at 724 municipalities and 880 industrial plants in at least parts of 9 states and the District of Columbia. Polluting wastes are discharged by 1,424 municipalities and 1,784 industries not connected to municipal sewer systems. Treatment facilities of some type are provided by 873 municipal and 702 industrial plants. Municipal pollution sources require 439 new plants, enlargements or additions to 224 plants, and replacement of 61 plants. Industrial waste sources require 683 new plants, additions or enlargements to 184 plants, and replacement of 13 plants. No projects are required at 520 municipal and 426 industrial locations. Project needs are undetermined for 180 municipal and 478 industrial pollution sources. During 1946–9, 63 municipal and 127 industrial plants were constructed or enlarged. In addition, corrective measures have been initiated for 378 municipal and 163 industrial sources of pollution.

H. P. Orland

Authorization of Revenue Bond Issues in California. By Stephen B. Robinson. *Jour.*, Amer. Water Works Assn., **43**, 2, 113 (1951).

This paper reviews and comments on the complex legal problems that have arisen from California revenue bond legislation and previous court cases. Practically all difficulties revert back to the state constitution requirement that no city (and no other of several enumerated classes of public bodies) shall incurr any indebtedness exceeding its ordinary annual revenue unless the approval of two-thirds of the voters is obtained and provision is made for a tax to meet the interest and provide a sinking fund for the payment of the principal. The courts have upheld this provision, but some board interpretations have modified it in specific instances.

Two procedures are open to California cities for the issuance of revenue bonds. First, a city has the power to issue revenue bonds under the Sanitation, Sewer and Water Revenue Bond Law of 1941, except in the improbable event that its charter, expressly or by necessary implication, precludes it from so doing. Secondly, the principle of home rule for cities under city charters may support the issuance of such bonds under an existing charter, or any city, by adopting a charter or amending an existing one, may issue revenue bonds by procedures established by or under such charter. However, test cases might be necessary in some circumstances to clarify the Sanitation, Sewer and Water Revenue Bond Law of 1941; and test litigation would be necessary to overcome a former court decision, unless provision is made by charter for the creation of a separate department and such bonds are issued by it.

Robert P. Lowe

Some Factors in the Treatment of Sewage in Percolating Filters. By T. G. Tomlinson and H. Hall. Presented at (British) Publ. Works and Munic. Services Congress (Nov., 1950).

This paper reports the results of a test in which seven identical trickling filter units were loaded at rates of from 100 to 1,000 g.p.d. per cubic yard (0.92 to 9.2 m.g.a.d.). The filters were 6 ft. deep and contained $\frac{3}{4}$- to $1\frac{1}{2}$-in. crushed gravel media. An eighth filter contained $1\frac{1}{2}$- to 3-in. smooth gravel and was loaded at 600 g.p.d. per cubic yard (5.5 m.g.a.d.). Applied sewage averaged 166 p.p.m. B.O.D. and 69 p.p.m. suspended solids. The test was run from June 1949 to June 1950. It was concluded that removal of B.O.D. was a straight-line function above rates of 450 g.p.d. per cubic yard and that below that rate deviation from the line was marked, probably due to nitrification. The weight of oxidizable matter removed increased, although the proportion of applied B.O.D. removed decreased as the rate of application increased. Settlement of solids from effluents was better at lower rates of operation. The weight of oxidizable matter removed increased markedly with increase in strength of applied sewage. Considerable ponding resulted at rates above 450 g.p.d. per cubic yard, especially in filters employing the smaller stone. Some ponding occurred in the larger rock at 600 g.p.d. per cubic yard.

At the conclusion of the test, the medium was removed and samples were taken at different depths for determination of total organic matter and the proportion of fungus mycelium and animal matter. These data show that appreciable film

occurs at all depths and that at higher rates the amount decreases with depth; the amount at the bottom was about half that at the surface.

An attempt to calculate the time characteristic of purification in filters using the monomolecular law of removal of B.O.D. and the time of contact in the filter resulted in values of the velocity constant, K (t in minutes), of about 0.047 (base 10). This is compared with rates of 0.00007 for B.O.D. oxidation (Phelps), and 0.0048 to 0.015 for first-stage activated sludge (Moore and Butterfield).

G. R. GRANTHAM

Report of the International Joint Commission, United States and Canada, on Pollution of Boundary Waters (1951).

A treaty between the United States and Great Britain signed in 1909 stipulated "that boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health and property of the other side. . . ." A joint committee was set up to determine: (1) if said waters are being polluted to the detriment of the other side, (2) the extent of the pollution, (3) remedial measures, and (4) a definite program for remedy of such conditions. A set of boundary waters quality control objectives prepared as a guide in the definition of remedial measures was published as part of an article in THIS JOURNAL, **23**, 4, 508 (Apr., 1951).

The report is divided into three parts embracing the Lake Huron—Lake Erie section, the Lake Superior—Lake Huron section, and the Lake Erie—Lake Ontario section.

Lake Huron—Lake Erie Section

The results of this section of the survey and the recommendations of the Technical Advisory Board are contained in an article in the previously mentioned article in THIS JOURNAL.

The cost of remedial measures is estimated as follows:

Cost for municipalities (interceptors and primary treatment):	
United States side	$35,000,000
Canadian side	16,000,000
Cost for industry:	
United States side	13,000,000
Canadian side	3,000,000
Total	$67,000,000

For secondary treatment of municipal sewage, additional costs are:	
United States side	$33,000,000
Canadian side	4,000,000
Grand total	$104,000,000.

The cost of adequate control measures is the factor which is holding back the solution of the pollution problems.

Lake Superior—Lake Huron Section

The drainage area of the St. Marys River is small, but the average discharge is 72,600 c.f.s. Current velocities are less than 1 m.p.h. in the upper river and 1.5 to 2 m.p.h. in the lower river.

The principal cities, with respective populations of 17,300 and 29,700, both draw domestic water from the river. Untreated sewage is discharged into the river through numerous outlets on both sides. These waters are important in navigation, power generation, and industry. Recreational uses are mentioned. The volume of municipal waste discharged amounts to 6.6 m.g.d. Five major industrial plants (2 in the U. S. and 3 in Canada) discharge daily as follows:

	Canada	U. S.	Total
Wastes (m.g.d.)	,146	2.4	148.4
Phenols (lb.)	280	0	280
NH_4 comp. (lb.)	3,500	0	3,500
Cyanide (lb.)	3,170	0	3,170
Oils (U. S. gal.)	1,020	0	1,020
B.O.D. (lb.)	217,900	7,800	225,700
Susp. sol. (lb.)	75,000	4,800	79,800

Wastes from navigation amount to 30,000 g.p.d. Bilge water is also a factor in pollution.

The public health significance of the pollution lies in the effects on water supplies. Chlorination has been effective in the control of disease. The danger is apparent in the upper end of the lower river where average M.P.N. values exceed acceptable limits. Phenols in this reach are high enough to interfere with the development of water supplies.

The Advisory Board recommends immediate initiation of construction of primary treatment and chlorination facilities for all domestic wastes from both cities, industrial effluents control, and sewage retention tanks for vessels. Estimated costs to comply with the objectives are:

Cost to municipalities:	
U. S. side	$1,250,000
Canadian side	2,750,000
Cost to industry:	
U. S. side	150,000
Canadian side	350,000
Total	$4,500,000

Lake Erie—Lake Ontario Section

The two lakes are connected by the Niagara River, a 37-mi. long stream divided at the approximate midpoint by Niagara Falls. Below the falls the river is narrow with velocities up to 30 m.p.h. In the lower 7 mi. the river widens and is quiescent enough to allow river traffic. River flow averages 202,000 c.f.s., with variations due to lake levels, winds, ice jams, and other factors. About 58 per cent flows over the falls, the balance being diverted for power purposes. About 84 per cent of the diverted water is returned to the river below the falls.

About 1,125,000 persons live in this section, with about 70 per cent living on the U. S. side of the upper river. About 1,000,000 persons are supplied domestic water in amounts approximating 220 m.g.d. All municipal supplies receive complete treatment with taste and odor control. The river receives sewage flows amounting to 230 m.g.d. from outfalls located along the river. Sewers are of the combined type, allowing discharge of slugs of untreated waste during storms. Treatment facilities are provided for 92 per cent of the sewered population, with 70 per cent manifest in the Buffalo plant. Secondary treatment is afforded the waste of 5 per cent of this population. Exclusive of the water used for steam power, industry uses 500 m.g.d., with 155 m.g.d. drawn from Lake Erie, 124 m.g.d. from the Buffalo River, and 183 m.g.d. from the upper Niagara River. About 60 per cent is returned to boundary waters, 30 per cent is returned through tributaries, and 10 per cent is discharged to municipal sewers. Industrial discharges are summarized as follows:

		U. S. Side	Canadian Side	Total
Total flow (m.g.d.)	Lake Erie	155	0	155
	Niagara River	305	36	341
Phenols (lb.)	Lake Erie	120	0	120
	Niagara River	6,250	0	6,250
Cyanides (lb.)	Lake Erie	0	0	0
	Niagara River	1,720	35	1,755
NH_3 comp. (lb.)	Lake Erie	5,530	0	5,530
	Niagara River	655	4,380	5,035
Oils (U. S. gal.)	Lake Erie	990	0	990
	Niagara River	900	0	900
Susp. sol. (lb.)	Lake Erie	180,900	0	180,900
	Niagara River	567,200	9,030	576,230
B.O.D. (lb.)	Lake Erie	[1]	0	[1]
	Niagara River	96,000	[1]	96,000+

[1] Undetermined.

There is no industrial discharge into Lake Ontario. Pollution from navigational uses of the upper river is considered significant. Pleasure boating, limited swimming, and fishing constitute recreational uses.

The main body of water at the eastern end of Lake Erie is of good sanitary quality, as are the waters along the Canadian shores of the upper river. The high velocity in the upper river below Buffalo tends to cause stratification of wastes along the shore and in the East Channel. In this pollution zone, which extends along the entire channel, M.P.N. values vary from 3,000 to 10,000 and phenols average 10 to 50 p.p.b. B.O.D. values average less than 2 p.p.m. B.O.D. values in the lower river are below 2.2 p.p.m. In Lake Ontario, relatively unpolluted water prevails at an offshore distance of 10 mi. There is a transfer of pollution from each side of the boundary, especially in the lower river, but it is not

feasible to state the amount of pollution so transferred.

The water quality in the upper river in places is unsuitable for public water supply. Economic losses are reflected in higher water treatment costs, extension of water intakes, and physical damage or destruction to watercraft and wildlife. The Board of Technical Advisors is of the opinion that reasonable stream sanitation consistent with the uses of these waters will be maintained if the wastes are treated to a degree which will result in a median M.P.N. value not to exceed 2,400 per 100 ml. at any point following initial dilution. It will be necessary to provide sufficient treatment of other substances which may injuriously affect the water.

The estimated cost of an adequate control program is as follows:

Cost to municipalities:	
U. S. side	$7,250,000
Canadian side	2,250,000
Cost to industries:	
U. S. side	4,000,000
Canadian side	100,000
Lake Erie cooling water project[1]	5,500,000
Grand total	$19,100,000

[1] Project involves pumping Lake Erie water to Buffalo industries to provide cooling water and further dilution for the badly polluted Buffalo River. G. R. GRANTHAM

Estimation of Oxygen Consuming Value of Coke Plant Aqueous Wastes. By JOSEPH A. SHAW. *Anal. Chem.*, **23**, 1764 (1951).

The author recommends the use of a short-time test with chromic acid at 100° C. for obtaining an oxygen consumed value. A 2.5-ml. sample is added to a test tube along with a standard chromic acid solution plus a one to one mixture of orthophosphoric and sulfuric acids. The ratio of the quantity of acid to water present, as well as the amount of chromic acid, is very critical. The mixture is heated in a steam bath at 100° C. for 5 min. It is then transferred to a flask for titration. An excess of ferrous ammonium sulfate is added and the excess titrated with the original chromic acid solution.

The results show a very high oxidation of the organic compounds studied. They agree very well with the reflux methods which have recently been published, possibly because of the high ratio of concentrated acid to the aqueous volume of the sample in spite of the lower temperature used. R. S. INGOLS

Sensitive 4-Aminoantipyrine Method for Phenolic Compounds. By M. B. ETTINGER, C. C. RUCHHOFT, AND R. J. LISHKA. *Anal. Chem.*, **23**, 1783 (1951).

A complete study of the use of 4-aminoantipyrine for determining phenol is reported in this article. A good color relatively free from interferences can be obtained at pH 9.8 to 10.2 according to these authors. Greater sensitivity is possible by extraction of the color from low concentrations into chloroform and comparisons with standards made in the organic solvent. Slight variations in ordinary room temperature have little effect on the reactions, but the color compound is relatively unstable. The method can detect phenol to 2 p.p.b. R. S. INGOLS

Determination of Phenols in Aqueous Wastes from Coke Plants. By JOSEPH A. SHAW. *Anal. Chem.*, **23**, 1788 (1951).

Two methods are described in this paper. The first is a rapid turbidometric procedure which is accurate for concentrations of phenol in excess of 30 p.p.m.; the second is dependent on the color developed from the reaction between phenol and 4-aminoantipyrine.

To use either procedure, concentration and purification steps may be required as a preliminary preparation of the phenol. The phenol is concentrated by acidifying the water to approximately pH 4.0 and extracting into ether. The phenol is removed from the ether by extracting with a 10 per cent sodium hydroxide solution. Purification is carried out from the alkaline extract after acidification by passing an air stream through the phenol solution in the presence of steam heat. At this point, the phenol is in a small volume and in a relatively pure form.

For the high concentration of phenol, the concentrated solution prepared above is treated with bromine and the resulting turbidity compared with standards. For the lower concentrations, the phenol solution is adjusted to pH 10.4±0.1 with ammonium hydroxide and 4-aminoanti-

pyrine is added. After mixing, some ferricyanide solution is added to bring out the color by oxidation. R. S. INGOLS

Indirect Colorimetric Micro-Oxidimetry of Organic Compounds. By H. T. GORDON. *Anal. Chem.*, **23**, 1853 (1951).

A number of specific procedures for organic radicals are given. The excess of the oxidants used are back titrated by using solutions of the reduced form of redox dyes. The reactions do not give complete destruction of the organic compound, but only enough of a reaction to identify the reactive group. The reactions are carried out at high dilution (0.10 p.p.m.) in small samples. R. S. INGOLS

Detection and Estimation of Free and Combined Chlorine Residuals. By ISADORE NUSBAUM AND PETER SKUPEKO. *Anal. Chem.*, **23**, 1881 (1951).

A method that has been published for determining cyanides is now recommended for the determination of chlorine. Cyanide is added to the sample to be tested for total chlorine. The chlorine and cyanide form cyanogen chloride, which can specifically react with pyridine in the presence of benzidine. The latter reaction is carried out in butyl or amyl alcohol because it is much more sensitive in the alcohol than in the water phase. The extraction of the cyanogen chloride into the alcohol also gives a clear medium for instrumental comparison of the color intensity with standard solutions, which is impossible in the presence of sewage turbidity.

Sodium arsenite is added to destroy any hypochlorous acid (which is not present in sewage) and the combined chlorine can then react with the cyanide to form cyanogen chloride. This permits a differentiation of free and combined available chlorine. Free bromine or iodine can be determined by this technique or may interfere with the determination of chlorine.

Nitrites, manganese, and ferric ions do not interfere, even in high concentrations (50 p.p.m.). Cyanides originally present in a sample of sewage to be analyzed will interfere, but can be determined as a zero correction. R. S. INGOLS

Polarographic Determination of Iodine in Water, Soil, and Plant Material. By P. R. GODFREY, H. E. PARKER, AND F. W. QUACKENBUSH. *Anal. Chem.*, **23**, 1850 (1951).

Iodine is determined in large volumes of water by concentration and separation by distillation. Organic matter is oxidized by using chromic acid during the concentration step and the excess chromic acid is destroyed by continued heating at 220° C. Iodine is distilled over and oxidized with ozone to iodate. The iodate solution is concentrated and then analyzed polarographically.

The method has been used in an iodine survey of public water supplies and plants grown in Indiana. Results for water are reported in parts per billion.

R. S. INGOLS

Sewage Treatment by Flotation with Detergents. By M. NEWE, J. SCHMIDT, AND A. SZNIOLIS. *Gaz, Woda i Technika Sanitarna* (Poland), **25**, 6, 176 (June, 1951).

By way of introduction, reference is made to studies on flotation with sewage reported by Hansen and Gotaas (1942), with laundry wastes by Eliassen and Schulthoff (1948), and with water by Hopper (1945). Beyond these studies the literature relative to the use of flotation in the water and sewage fields is very meager. For a theoretical discussion of the problem, the authors turned to the extensive literature on mineral flotation. In this study the authors studied the effect on sewage treatment of the addition of 28 different detergents belonging to several groups, namely: nonionic (Sterox SE, Sterox 6, Miragen T (powder), Mirogen T (fluid); anionic (Duponol 189, Duponol 189-S, Alkanol WXN, Merpol B, Merpol C, Miranol CL, Miranol LF, Parnol, Nytron); cationic (Miranol OH, Miranol QCK); and unspecified (Detergent 240, Ahcowet ANS, Anhydrous Ahcowet RS, Santomerse D, Santomerse No. 3, Nacconol NR, Nacconol NRSF, Lomar PW, Tergitol 08, Tergitol 4, Tergitol 7, Tergitol P-28, Product BC). In all studies municipal sewage, which had been settled for 2 hr. in an Imhoff cone, was used. The detergents were dissolved in water, such that 1 ml. of the resulting solution was equivalent to 10 mg. of detergent. In Series I, to 800 ml. of sewage variable

amounts of detergent (10, 20, 30, 40, 60, or 100 mg. were added, followed by 5- to 10-min. aeration. All detergents were studied, and all showed similar results; a slightly lighter colored solution and a slightly darker foam. In Series II, the effect of the addition of acids, bases, salts, etc., was studied. These were added to 800 ml. of sewage containing 8 mg. detergent. With 2 ml. of conc. HCl, good results were obtained; the liquid was transparent and the foam very dirty. Treatment at a pH of 1.6 to 1.8 yielded the best results. Acid treatment without detergents showed no removal. In Series III and IV use was made of H_2SO_4 and H_3PO_4 in place of HCl. Results similar to those reported with HCl were obtained, which indicated that pH was of primary importance rather than the kind of acid used. In Series V and VI organic acids (acetic and citrus) were used, and it was found that these acids were quite effective at a pH of 2. When mineral acids were used, the turbidity was reduced to 3 to 5 mg. per l. SiO_2 and with organic acids to 50 mg. per l. SiO_2. However, foaming was more extensive with the organic acids and the foam was finer textured. In Series VII to the sewage and detergent a wide variety of other materials were added such as chlorine water, NaCl, NaOH, and alum. Results were unsatisfactory and were similar to those reported for the detergents alone when added to the sewage. It was noted, however, that with alum there was extensive foaming without the addition of detergent, and when acid was added with the alum excellent removals were obtained. With the use of 50 mg. of 1 per cent alum per liter of sewage at a pH of 3.5, excellent removals were reported—the turbidity was reduced to 3 mg. per l. SiO_2. The following conclusions and recommendations are listed by the authors: (1) Flotation as a means of sewage treatment with the aid of detergents yielded no positive results when 10 to 100 mg. per l. of 28 different detergents were added to the sewage. (2) Flotation of sewage with the addition of 10 mg. per l. of detergent to an acidified sewage (pH about 2) resulted in 90 to 99 per cent reduction of suspended solids, 65 per cent reduction of the 5-day 20° C. B.O.D., and about 60 per cent of the oxygen consumed. (3) Flotation of sewage with the addition of alum in an acid solution (pH 2.0 to 3.5) gave better results in less time than when detergents were added. (4) The negative results reported for the 28 detergents studied (when no acid was added) do not necessarily mean that other detergents might not be effective. (5) The need for acidification with the available detergents reduces the value of this method of sewage treatment; however, this method may find possible use in the treatment of acid industrial wastes. (6) The excellent results obtained with alum point to the possibility of using flotation as a means of obtaining rapid coagulation through the use of various coagulating agents—the process might be used for coagulating water and for iron removal without the need for filtration. CONRAD P. STRAUB

The Development of Water Supply and Sewage Disposal and Treatment Under the Six-Year Plan. BY JOZEF LIEBFELD. *Gaz, Woda i Technika Sanitarna* (Poland), **25**, 7–8, 193 (July-Aug., 1951).

Sewer systems are available in 326 Polish cities, or 46.2 per cent of the total number of cities. There remain, therefore, 379 cities without sewer systems, and in which the sewage is collected in septic tanks, pits, and privies. These systems frequently are the cause of subsurface and ground-water contamination. Sewer systems are present in 169 rural communities, mainly in the western provinces, and they represent a very small percentage of the total number of rural communities. The percentage of sewered municipalities increased following World War II (because of the many sewer systems in the former German territories assigned to Poland); the situation was much worse during the period between the two wars. Sewage treatment plants are found in 186 cities and 41 rural communities, but only 39 plants employ secondary treatment. With respect to the treatment of industrial wastes the situation is far worse. These data tell only part of the story, inasmuch as many of the sewer systems are more than 40 years of age and will require extensive rehabilitation.

CONRAD P. STRAUB

Pollution of the Bystrzycy River in Summer. BY MARIAN STANGENBERG. *Gaz, Woda i Technika Sanitarna* (Poland), **25**, 7–8, 227 (July-Aug., 1951).

During June and July, 1950, 35 samples were collected from various points on the Bystrzycy River (a tributary to the Oder

River), its tributaries, and several industrial plants on the watershed. On the basis of chemical, physical, and bacteriological tests the river is in a satisfactory sanitary state only at its source, and for a short distance beyond; however, most of the river may be likened to an open sewer. When compared with similar data reported for 1949, it is found that the pollutional load on the river had increased. To improve the sanitary conditions in the river it is recommended that (1) all industries and municipalities should activate all treatment plants that are available but not in use; (2) where no treatment facilities are available and they are needed, these should be designed and constructed; and (3) all rehabilitated and newly constructed plants be required to submit reports of operation.

CONRAD P. STRAUB

The Desalting of Saline Waters: A Review of the Present Status. BY EDWARD W. MOORE. *Jour.*, New England Water Works Assn., **65**, 4, 319 (1951).

The article is taken from a report by the author to the Subcommittee on Water Supply, Committee on Sanitary Engineering and Environment, Division of Medical Sciences, National Research Council.

The author discusses the objections to high salt content in potable water supplies, based on taste and physiological effects, indicating observed limits. High salt concentrations are also objectionable in agriculture and may be troublesome in industry. There is a real need for an economical process to reduce the salt content of saline waters, preferably to less than 500 p.p.m., and, in any case, less than 1,000 p.p.m., and at the same time eliminate any toxic ions which may be present.

At present only two methods of desalting saline waters approach economic feasibility —evaporation and ion exchange demineralization. The choice is determined largely by the cost, mobility, and other engineering factors.

Electro-osmosis and freezing have been given some consideration.

Various alternatives are discussed.

Cost and operating requirements are discussed along general lines, although exact data are not available.

The bacteriological quality of desalted water will probably be good from direct-fired evaporators and vapor compression stills. The physical quality should also be good.

Tastes and odors, however, may persist and be met by subsequent treatment. The comparative water yields per unit of material consumed are discussed, as well as the comparative size and weight of equipment, and scale control.

LANGDON PEARSE

University Research. Tech. Paper No. 24, Univ. of Florida. (Jan., 1949).

Facilities for sewage treatment research have been installed by the University of Florida to study the needs of the smaller communities and the use of available materials. The facilities consist of 32 independent units of pilot plant dimensions. Included are a pumping station; two types of primary treatment tanks (each about 30,000 g.p.d. capacity); eight intermittent sand filters; six 8-ft. deep trickling filters, equipped for sampling at depth intervals of 2 ft.; individual secondary settling tanks for each trickling filter; two sludge digesters; sludge drying beds; final chlorine contact tank; and laboratory. There is also the main campus treatment plant. Subsurface sewage disposal has also been studied and a percolation coefficient developed for various soils.

LANGDON PEARSE

Review of the Report of the President's Water Resources Policy Commission. BY SAMUEL B. MORRIS. *Jour.*, Am. Water Wks. Assn., **43**, 6, 391 (June, 1951).

This review, by one of the members of the President's Water Resources Policy Commission, goes into some of the background of the work of the Commission that finally culminated in the report. It is by no means a criticism of the Commission's work, but instead presents additional material in support of the findings and recommendations. ROBERT P. LOWE

Water Policy as the Engineers See It. BY ABEL WOLMAN. *Jour.*, Am. Water Wks. Assn., **43**, 6, 401 (June, 1951).

The author presents this critical discussion in his own typical style, bringing forth the viewpoints of those who are opposed to excessive federal expenditures and to domination of river basin developments by the central government. Broad experience from service with former water

resources groups enables him to present a number of pertinent points.

In particular, a good comparison is made between the principles enumerated in the report of the Engineers Joint Council and those of the President's Water Resources Policy Commission. Other comments make note of inconsistencies in the report, as it is stated that a sharp contrast exists between the enunciation of the principles and the implementation of the policy that should follow from the principles. The suggestion is made that possibly the variety of people who took part in the compilation of this document were not able to keep in complete accord on consecutive page statements.

ROBERT P. LOWE

Objectives of a National Water Policy. BY MALCOLM PIRNIE. *Jour.*, Am. Water Wks. Assn., **43**, 6, 409 (June, 1951).

A critical comparison is drawn between river basin development on the state level as represented by the Interstate Commission of the Delaware River (Incodel) and development based more on federal participation as presented in the report of the President's Water Resources Policy Commission. The basis for federal action is discussed in detail in order to present limitations that will make interstate action more desirable.

ROBERT P. LOWE

Relationship of Water and Sewage Works Financing. BY JOHN W. CUNNINGHAM. *Jour.* Amer. Water Works Assn., **43**, 11, 937 (1951).

The definite trend to the method of sewer-user service charges is discussed. These charges have been widely adopted in place of general ad valorem taxation for trunk sewers, treatment plants, and sewer outfalls. In a few instances where the entire sewer system and treatment plant have been financed, Oregon and Washington communities pay as much as $1.75 to $2.50 per month. However, it is stated that 25¢ to 50¢ per month should be adequate to finance a sewage treatment plant and sewer outfall.

Collection of water and sewer charges on the same bill is covered in detail, and it is stated that the bill should place them as separate items in order to be fair to the customer. Lateral sewers should be financed by assessments, as the enhancement of property values is local, and the burden should not be borne by the community as a whole.

Dangers in the practice of consolidation of water and sewage departments are also cited. For financing and rate purposes enough difference exists between sewage and water operations to characterize them as separate entities. Even under consolidated management, no difficulty arises from keeping separate accounts whereas if everything is listed under a single heading the results are likely to be damaging to the water department and grossly unfair to the water-rate payers.

ROBERT P. LOWE

On the Sensitivity of the Methane Fermentation of Calcium Acetate Towards Some Toxic Substances. BY H. F. BANNICK AND F. M. MULLER. *Antonie van Leeuwenhoek*, **17**, 171 (1951).

Experiments conducted with the addition of various toxic substances to a substrate containing calcium acetate and purified enrichment cultures of methane bacteria showed the following: (1) Sodium sulfate at 126 p.p.m. concentration had no inhibiting effect but there was a 70 per cent retardation as measured by gas production at 1,260 p.p.m. concentration; (2) hydroxylamine at 33 p.p.m. concentration exerted a 49 per cent retarding influence and at 10 times this concentration the retardation was nearly complete; (3) phenylhydrazine had a retarding influence at 108 p.p.m. and a nearly complete inhibition at 10 times this concentration; (4) sodium azide had a retarding influence at 65 p.p.m. concentration and nearly a complete inhibiting effect at 10 times this concentration; (5) potassium cyanide had a complete inhibiting effect at 65 p.p.m. concentration and a nearly complete inhibition at 33 p.p.m.; (6) sodium sulfide had no retarding effect at 780 p.p.m. concentration, but nearly a complete inhibiting influence at 3,900 p.p.m.; (7) formaldehyde affected the gas production from calcium acetate, but the cultures could be acclimatized to 15 per cent formaldehyde. The gas produced from formaldehyde additions consisted of equimolecular proportions of CH_4 and CO_2.

H. HEUKELEKIAN

Book Reviews

Industrial Wastes: Their Conservation and Utilization. By Charles H. Lipsett. Atlas Pub. Co., New York, N. Y. (1951). 317 pp. Price, $5.00.

Ranging over a wide field of essential wastes, the book covers plastics, chemicals, textiles, rubber, paper, leather, steel, wood, glass, as well as organic wastes, paints and solvents, agricultural wastes, etc. For those concerned with wastes production, salvage, and utilization the book may have some interesting semi-technical information. From the standpoint of the sanitary engineer it should be noted that the book deals almost exclusively with solid wastes of the type normally considered as scrap. Also, in most cases, the material is not actually waste at all, but rather forms the basis of salvage or by-product recovery.

Air Pollution (Proc. of U. S. Tech. Conf. on Air Pollution). Louis C. McCabe, Chairman. 847 pp. Price, $12.50. McGraw-Hill Book Co., Inc., New York, N. Y. (1952).

This volume brings together much useful information on air pollution, as presented by outstanding authorities on the seven panels at the United States Technical Conference on Air Pollution. Authoritative data relating to many aspects of this present-day problem are presented.

The wide scope of the subject matter and the recognized eminence of the authoritative sources make this a practical guide for anyone concerned in any way with the problems of air pollution. The seven panels dealt specifically with air pollution effects on human, plant, and animal health; measures and equipment necessary for prevention and control; and legal and administrative phases.

Water. By Cyril S. Fox. 148 pp. Price, $8.75. The Philosophical Library, Inc., New York, N. Y. (1952).

This treatise deals with a study of the properties of water, its constitution, its circulation on the Earth, and its utilization by man. As such it is a highly interesting and readable volume, although it has little to offer wastes treatment and pollution control personnel from a technical viewpoint.

Nomenclatura de Ingenieria Sanitaria (Sanitary Engineering Nomenclature). By Victor Jose Moya. Publ. Rolland, Mexico, D. F. 152 pp. No price indicated. (1952).

This original English-Spanish glossary of sanitary engineering terms marks an important contribution to the development of sanitary engineering in Spanish-speaking countries. Much of the development in this field has been in the U. S. A. and England, with establishment of a terminology in many cases not capable of accurate translation into Spanish. The present book points out the difference between the words and ambiguous idioms for 3,700 terms encountered in the technical literature and commercial advertising.

Engineering in Public Health. By Harold E. Babbitt. McGraw-Hill Book Co., Inc., New York, N. Y. (1952). 582 pp. Price, $8.00.

This new text emphasizes the breadth of knowledge required by the engineer in public health. Early chapters constitute an introduction to the entire field, its aims, the nature of workers' duties, and needed administration for efficient functioning.

Besides thorough coverage of important details and discussion of the many related functions involving the engineer in public health work, the book deals with such recent advances as new pesticides, poisons, and fumigants, recent developments of equipment for high-temperature-short-time pasteurization, diatomite water filters, odor and its control, fluoridation of water, and disinfection of air with aerosols and ultraviolet rays.

The book should be extremely informative and useful to both the professional engineer practicing in the field of public health and the student of engineering in the control of environment for protection of human health and promotion of comfort.

Handbook of Engineering Fundamentals. Second Edition. OVID W. ESHBACH, editor. John Wiley & Sons, Inc., New York, N. Y. 1324 pp. Price, $10.00.

The second edition of this well-known handbook brings together revised and up-to-date material in 14 major branches of fundamental engineering activity, as compiled by some 39 outstanding contributors. In general, the new edition eliminates those features of the first edition (1936) considered too elementary for inclusion and avoids material so advanced as to be of interest only to a few specialists in the various fields.

The book makes a good desk reference, its wealth of material being easily usable through the facility of its 52-page detailed index.

The Municipal Year Book, 1952. CLARENCE E. RIDLEY AND ORIN F. NOLTING, editors. International City Managers' Assn., Chicago, Ill. 604 pp. Price, $10.00.

The 19th annual volume of this signifi cant compilation of municipal data brings up to date all the regular sections of the Year Book and also extends its coverage to the following:

1. Final 1950 census population figures for each city over 5,000, with an analysis of urban population changes.
2. Information on 200 New England, New Jersey, and Pennsylvania towns and townships.
3. Individual city finances for cities between 5,000 and 25,000 population.
4. Planning and zoning information for all cities over 10,000.
5. Traffic safety information for representative cities.
6. Individual city data for municipally-owned electric utilities in cities over 5,000 population.

As in previous volumes, articles in each field of municipal activity review the significant events of the past year and summary articles preceding each major table analyze data reported by hundreds of cities.

This is a reference work usable by every department in a city, not only in its everyday work, but also in public relations policies.

Industrial Waste Treatment. BY EDMUND B. BESSELIEVRE. McGraw-Hill Book Co., New York, N. Y. (1952) 391 pp. Price, $7.00.

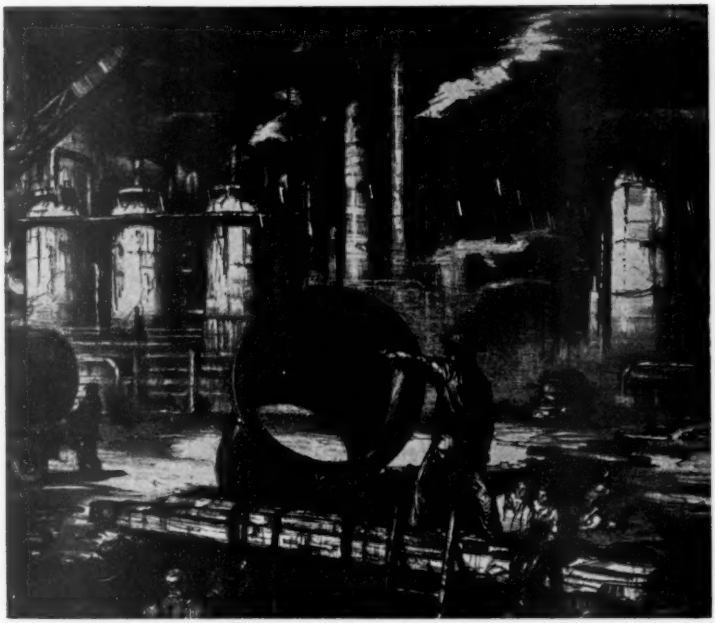
This unusual book is written primarily for industrialists at the management and technical levels, as it is these individuals who must make the decisions and supervise pollution abatement procedures in their own plants.

The first nine chapters encompass an excellent guide to the proper approach to the solution of an industrial waste problem. The last eight chapters deal mainly with methods of handling wastes.

Considerable in the way of basic analytical data on a broad variety of wastes is included in Chapters 11 and 12, which deal, respectively, with the "Pollutional Effect of Various Wastes" and "Methods of Wastes Treatment." In the latter chapter, flow diagrams are employed well to illustrate treatment procedures. In Chapter 13, on "Selection of Waste Treatment Equipment," the discussion of equipment is almost entirely confined to one company (Dorr), at least as far as illustrations are concerned.

Generally, this book is a very good one, unique among others now available because of the coverage of the first nine chapters. It should prove a great aid to industry in its understanding of the water pollution problem and of the means toward overcoming it.

H. P. ORLAND



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Proceedings of Member Associations

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 37th Annual Meeting of the New Jersey Sewage and Industrial Wastes Association, held at the Hotel Traymore, Atlantic City, N. J., March 12–14, 1952, drew a near-record registration of 347.

Papers presented at the technical sessions included:

"Aeration—A Successful Treatment of Dairy Wastes," by G. E. Hauer, Chief Engineer, and G. A. Fleet, New York District Manager, American Well Works.

"Starting-Up Experiences at Philadelphia," by Ralph A. Hoot, Superintendent of Sewage Disposal Plants, Philadelphia, Pa.

"Effects of Detergents on Sewage Treatment Processes," by R. Manganelli, Research Associate, Dept. of Sanitation, Rutgers University.

"Foam Control of Wastes Disposal," by W. B. Stevens, Staff Engineer, Socony-Vacuum Oil Co., New York, N. Y.

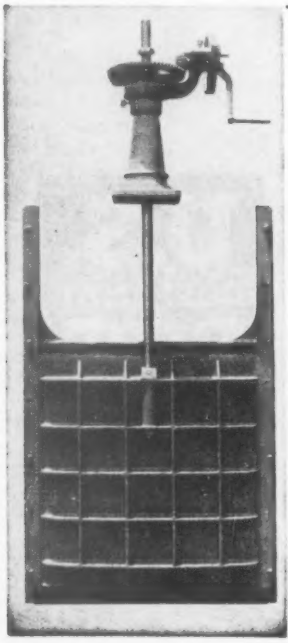
"Type S Parabolic Flume for Sewage Measurement," by Frank Sommer, Simplex Valve and Meter Co.

"Woods Irrigation Wastes Disposal Operations," by John M. Seabrook, Executive Vice-President, Seabrook Farms Co., Seabrook.

"Recent Improvements at the Plainfield Joint Meeting Plant," by Andrew Palmer, Superintendent.

"Activities of New Jersey in the Clean-Up of the Interstate Delaware

(*Continued on page 368a*)



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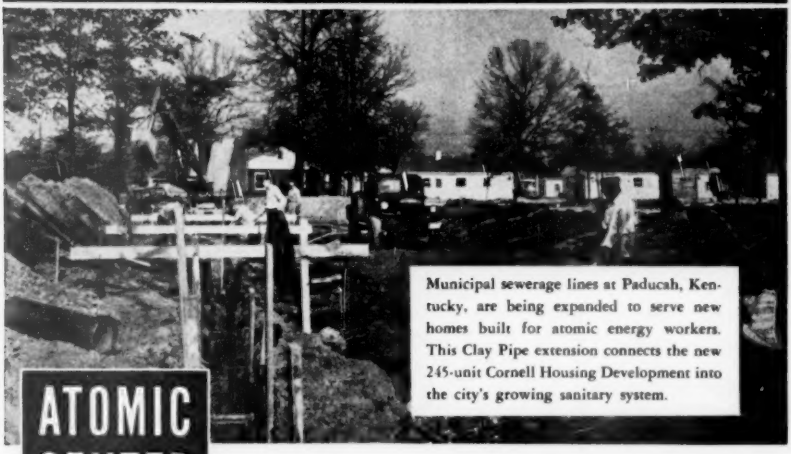

Municipal sewerage lines at Paducah, Kentucky, are being expanded to serve new homes built for atomic energy workers. This Clay Pipe extension connects the new 245-unit Cornell Housing Development into the city's growing sanitary system.

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Rapid City, S. D. (Air Force Base)	54,000 ft.
Orlando City, Fla. (Air Force Base)	74,000 ft.
Tucson, Ariz. (Air Force Base)	440,000 ft.
Morrisville, Pa. (New Steel Defense Plant)	300,000 ft.
Rantoul, Ill. (Chanute Field)	158,000 ft.

C-152-A

River," by John D. Cohen, Public Health Engineer for Incodel, assigned to N. J. State Dept. of Health.

"Aero-Accelator-Aero-Cyclator," by A. A. Kalinske, Director of Development, Infilco, Inc.

"Notes and Comments on Chlorine Demand Test," by Thomas M. Riddick, Consulting Engineer-Chemist, New York, N. Y.

"Public Relations from the Standpoint of a Sewage Works Operator," by W. H. Wisely, Executive Secretary, FSIWA.

"Sludge Disposal Experiences at the Elizabeth Joint Meeting Plant," by Leslie E. West, Chief Engineer.

"Wastes Disposal—A Joint Municipal and Industrial Problem," by Morris M. Cohn, City Manager, Schenectady, N. Y., and Editor, *Wastes Engineering*.

"Current Program of the Interstate Sanitation Commission," by Seth G. Hess, Director and Chief Engineer, Interstate Sanitation Commission.

"Loadings and Performances of High-Rate Trickling Filters Operated in Series and Parallel," by C. Bernard McMenamin, Superintendent of Sewage Treatment, Borough of Middlesex.

Also presented were films entitled "The Delaware—Water for Millions," by the Interstate Commission on the Delaware River Basin, and "Pipeline to the Clouds," by General Electric Co.

A highlight of the meeting was the annual "Speechless Dinner and Entertainment," sponsored by the Water and Sewage Works Manufacturer's Association.

The closing session of the meeting was devoted to the Operators' Breakfast and the Business Meeting. The Breakfast program consisted of a symposium stressing "Social Security Benefits for Municipal Employees" and "Control of Beach Pollution."

Officers elected to serve for the ensuing two-year period were:

President: Sol Seid, New Brunswick.
1st Vice-President: John W. Hood, Ridgewood.
2nd Vice-President: John Collom, Bordentown.
Secretary-Treasurer: M. S. Kachorsky, Manville.

M. S. KACHORSKY,
Secretary-Treasurer

VIRGINIA INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The 6th Annual Meeting of the Virginia Industrial Wastes and Sewage Works Association was held at the Hotel Roanoke, Roanoke, Va., May 12–13, 1952. Registration for the meeting was about 110.

The first morning and the last afternoon were devoted to inspection trips to the Roanoke and Vinton sewage treatment plants.

Other sessions heard panel discussions as follows:

(*Continued on page 370a*)

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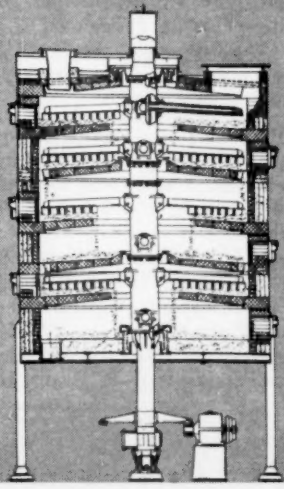
2. Trouble free operation, with low maintenance costs.
3. Lower labor costs through mechanical stoking.
4. Elimination of odor and fly ash nuisance.
5. Compact, attractive plant design.

Nichols Engineers are always ready to assist in solving municipal and industrial sewage sludge disposal problems.



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Engineering & Research Corp.
70 PINE STREET, NEW YORK 5, N. Y.
1920 N. Meridian St., Indianapolis 2, Ind.
40 S. Los Robles Ave., Pasadena 1, Calif.
1477 Sherbrooke St. W., Montreal 25, Canada

"What Has Been Done at Some Virginia Locations in the Past Five Years," by R. L. Morrison, A. S. Owens, and T. B. Noland, municipal managers of Bristol, Roanoke, and Franklin, respectively.

"Northern Virginia—The Problem, Its Background, and What's Being Done," by J. J. Corbolis, sanitary engineer, Fairfax County; C. L. Watkins, city engineer, Alexandria; F. H. Doe, sanitary engineer, Arlington County; and J. W. Head, director, Dept. of Public Works, Falls Church.

"What Has Been Done in Virginia and Elsewhere About Some Waste Disposal Problems in the Past Five Years," with John W. Rugaber, Pet Milk Co., Greenville, Tenn., discussing milk wastes, and T. J. Powers, waste disposal supervisor, Dow Chemical Co., Midland, Mich., discussing chemical wastes.

Other papers included:

"Industrial Waste Control and Treatment," by H. H. Black, U.S.P.H.S., Cincinnati, Ohio.

"What Every Operator Should Know," by M. M. Cohn, city manager, Schenectady, N. Y.

"Aeration Efficiency and Design for Sewage and Industrial Waste Treatment," by W. Eckenfelder, Jr., consulting chemist, Ridgewood, N. J.

"The Forest and the Trees," by W. H. Wisely, executive secretary of the Federation.

Previous to the Annual Banquet and Dance on the evening of May 12, a Social Hour sponsored by the Water and Sewage Works Manufacturers' Association was enjoyed.

At the Business Meeting a committee was appointed to set up an annual award recognizing superior plant service. Officers elected for 1952–53 were:
President: S. H. Reaves, Winchester.
Vice-President: S. R. Evans, Glasgow.
Secretary-Treasurer: J. L. Hamrick, Richmond.

J. L. HAMRICK,
Secretary-Treasurer

ARKANSAS WATER AND SEWAGE CONFERENCE

The 1952 Annual Meeting of the Arkansas Water and Sewage Conference was held at the University of Arkansas, Fayetteville, Ark., April 7–9, 1952. A total of 144 persons registered for the meeting.

In addition to the usual short school lectures and laboratory sessions, papers were presented as follows:

"Sewer Line Construction," by E. F. Bespalow, Vice-President and Chief Engineer, Choctaw, Inc., Memphis, Tenn.

"Operation of High-Rate Filters," by W. M. Smith, Engineer, Dorr Co., Dallas, Tex.

"Sewer Plant Operational Problems," by J. J. Highfill, Superintendent of Waterworks, Springdale.

"Safety in Water and Sewage Works," by H. M. Rheubush, Safety Director, City Water and Light Plant, Jonesboro.

"Conservation of Water," by Howard Degler, Technical Director, The Marley Company, Kansas City, Mo.

At the business meeting, Dr. Harrison Hale was nominated to receive the Federation's Arthur Sydney Bedell Award in 1953.

Officers elected to serve during 1952–53 were:

Chairman: J. J. Highfill, Springdale.
Vice-Chairman: J. Wilson, Little Rock.
FSIWA Director: G. T. Kellogg, Little Rock.
Secretary-Treasurer: Harrison Hale, Magnolia.

HARRISON HALE,
Secretary-Treasurer

FORT WORTH INSTALLS 6 PROCESS CLARIFIERS!

General view of Fort Worth, Texas Sewage Treatment plant. Consulting Engineers for the recent additions, Freese & Nichols. Contractor, Russ Mitchell, Inc. Plant operation under the direction of W. S. Mahlie, Sup't Water and Sewage Treatment.

Close view of one of the final clarifiers with a side feed influent arrangement.

The progressive city of Fort Worth, Texas, known for its contributions to the art and science of water and sewage treatment, has again made additions to the sewage treatment plant. These new facilities include six 95′ dia. Type C Process Clarifiers. Three of these are for sedimentation in the intermediate treatment step and three of the mechanisms are for the final sedimentation units.

If in need of clarifier mechanisms, investigate the modern, built-to-last and trouble-free Process Clarifier. Write to any address listed below for complete information.

PROCESS ENGINEERS INCORPORATED

212 SUTTER STREET
SAN FRANCISCO 8, CALIF.

6381 HOLLYWOOD BLVD.
LOS ANGELES 28, CALIF.

EASTERN AND MIDDLE WESTERN REPRESENTATIVE:
PACIFIC FLUSH-TANK COMPANY • 4241 RAVENSWOOD AVE., CHICAGO 13, ILL.

Equipment and Supply Lines

Lubricated Plug Valves—New Catalog 49–V describes complete line of ½-in. to 12-in. lubricated plug valves and accessories for corrosion-resistant service.—H. K. Porter Co., Inc., 1150 North Peoria St., Tulsa 1, Okla.

Motor Control Center—New Bulletin GEA–4979A describes make-up and applications of motor control centers employing standard components and assemblies.—General Electric Co., Schenectady 5, N. Y.

Gas Engines—Booklet entitled "The Modern Gas Engine" describes history and modern design developments of gas and dual-fuel engines.—Cooper-Bessemer Corp., Mt. Vernon, Ohio.

Process Machinery—New 8-page Bulletin 100–A describes a complete line of process machinery for many chemical, wastes, and sewage applications. The bulletin is divided into sections by actual process operations.—Hardinge Company, Inc., York, Pa.

Port and Butterfly Valves—Use of air-motor diaphragm operators with adjustable port valves is described in new 12-page Catalog No. 1800. A similar catalog (No. 1700) gives complete specification data for air-operated butterfly valves.—Brown Instruments Division, Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Instruments—Specifications of approximately 100 measuring and control instruments and valves are outlined in new Catalog No. 5000.—Brown Instruments Division, Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Masonry Drill Bits—Drilling of masonry ranging in hardness from asbestos to granite is simplified by carbide-tipped bits useable in electric rotary drills. The bits are made for 3/16-in. to 2-in. hole sizes, and in solid or hollow core styles. A new guide sheet and a performance data sheet are available.—New England Carbide Tool Co., Inc., 60 Brookline St., Cambridge 39, Mass.

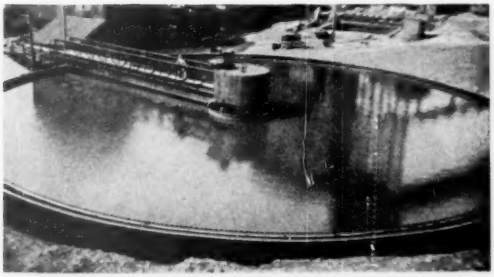
Piping Pointers—Under this title a new 32-page booklet gives many helpful hints on the application and maintenance of piping equipment, including valves, pressure regulators, fittings, joints, gaskets, packing, steam traps, and other accessories.—Crane Co., 836 South Michigan Ave., Chicago 5, Ill.

Variable-Area Flow Meters—Complete descriptions of variable-area meters, tubes, and floats, and their comparison with variable-head meters, as well as calibration prediction data, are included in a new 40-page handbook.—Fischer & Porter Co., Hatboro, Pa.

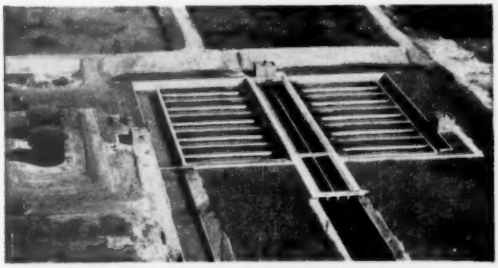
Rust Remover—A new chemical treatment designed for wipe-on application is claimed to remove rust, tarnish, and light oil, chemically prepare metals for paint, and retard corrosion. Known as "Rustclean," the compound cleans steel, iron, aluminum, zinc, cadmium, and copper and its alloys, and forms a phosphate coating that acts as a base for organic finishes.—Octagon Process, Inc., 15 Bank St., Staten Island 1, N. Y.

Proportioning Weir Tank—A new line of proportioning weir tanks for solutions or suspensions has been announced. Fitted with a pneumatic or electric operator, the splitter arrangement is said to be ideal for controlling the flow in proportioning systems or automatic pH control systems.—Omega Machine Co., 345 Harris Ave., Providence, R. I.

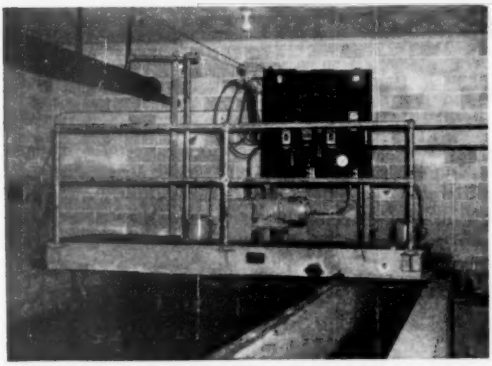
Plastic Pipe—Corrosion-proof plastic piping of flexible and rigid types for use in many applications is described in a new 4-page bulletin.—The Plastex Pipe and Extrusion Co., 402 Mt. Vernon Ave., Columbus 3, Ohio.



COAL—120'-diameter Hardinge Circular Clarifier removing 60 tons per hour of solids from coal breaker waste water.



OIL—Eleven Hardinge Rectangular Clarifiers (basic size 19.4' x 50.7') removing floating oil and sludge from oil refinery waste water.



SEWAGE—9' x 25' Hardinge Automatic Backwash Sand Filter on sewage settling tank effluent.

Hardinge

CIRCULAR CLARIFIERS, RECTANGULAR CLARIFIERS, AUTOMATIC BACKWASH SAND FILTERS, DIGESTERS, SLUDGE DRYERS.

Hardinge has installed waste water treating or reclaiming equipment for the following industrial operations:

COAL
PAPER
OIL
GLASS
LIME
STONE
SAND
FLUE DUST
CARBON BLACK
MEAT PACKING
RUBBER
DOMESTIC SEWAGE

Write for Bulletin 35-C-16

SEE A WORKING MODEL OF THE AUTOMATIC BACKWASH SAND FILTER IN OUR BOOTH AT THE NEW YORK SHOW, OCTOBER 6-9.

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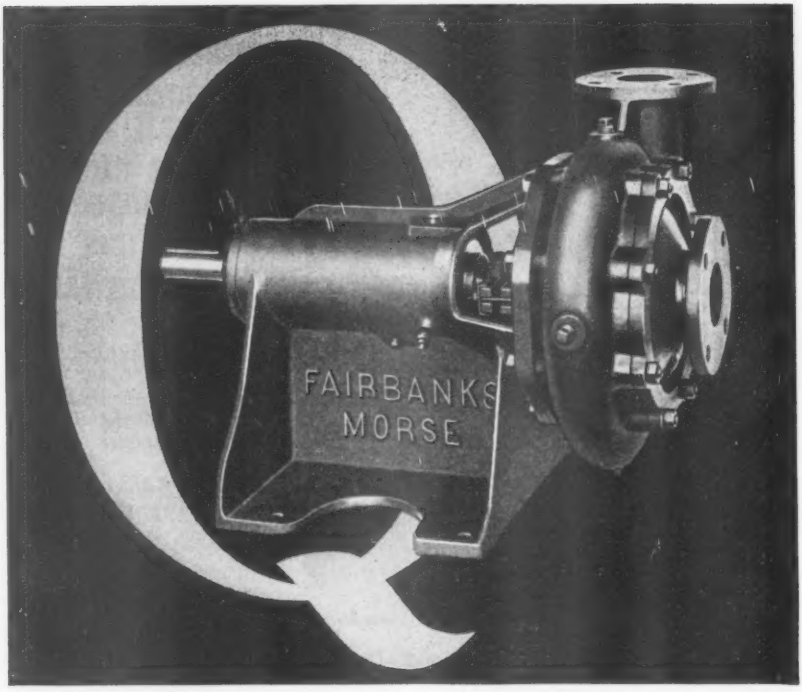
122 E. 42nd St. 24 California St. 205 W. Wacker Dr. 2016 First Ave. 200 Bay St.



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Quality . . . that costs no more is yours when you choose Fairbanks-Morse Side-Suction Centrifugal Pumps. Extensive engineering laboratories . . . production line methods with precision machining of all parts enable Fairbanks-Morse to offer you a side-suction centrifugal with the design, workmanship and performance normally obtained only in highest quality split-case pumps.

Open type, single suction, high efficiency impeller . . . ball-bearing frame construction for long life and smooth operation . . . one-piece, solid cast frame . . . close-grained smooth cast iron volute . . . are among the many big pump features you'll find in these moderate priced side-suction centrifugals.

For a "cue" to better pump performance, choose the pumps that spell quality with a capital "Q" . . . Fairbanks-Morse Side-Suction Centrifugals. Fairbanks, Morse & Co., 600 S. Michigan, Chicago 5, Ill.

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a name worth remembering when you want the best

PUMPS • DIESEL LOCOMOTIVES • ELECTRICAL MACHINERY • SCALES • HOME WATER SERVICE EQUIPMENT • RAIL CARS • FARM MACHINERY • MAGNETOS

INSTALLATION OF THE DOUGLASS AVENUE STORM SEWER IN 1909. ▲

LOCK JOINT PIPE COMPANY'S MODERN SEWER PIPE PLANT AT WICHITA. ▶

BACK IN 1909... Lock Joint Pipe Company first provided sewer pipe for the City of Wichita. In that year two 48" lines were installed. Both were built of Lock Joint Pipe, and both are in active use today.

Since that time Wichita has installed many other Lock Joint lines. Because, over the years, there has been continued local demand for Lock Joint sewer and culvert pipe, the Company has built one of its most modern and best equipped manufacturing plants in Wichita. Here sewer and culvert pipe in a wide range of sizes from 6" to 108" in diameter can be produced.

Similarly, in thirteen other cities and towns in the States and in Hato Rey, Puerto Rico and Caracas, Venezuela, Lock Joint Pipe Company has established permanent sewer and culvert pipe manufacturing plants. All are equipped to produce the most modern and efficient reinforced concrete pipe for such projects as sanitary sewers, storm drains, airport drainage, highway culverts and irrigation lines. To determine which Lock Joint plant can most conveniently serve you, consult our list of Branch Offices below.

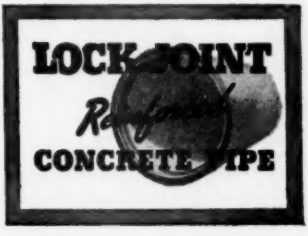
SCOPE OF SERVICES—*Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply Distribution Mains in a wide range of diameters as well as Concrete Pipes of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.*

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, N. J.

BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. • Denver, Col. Kansas City, Mo. • Chicago, Ill. • Valley Park, Mo. • Rock Island, Ill. Wichita, Kan. • Kenilworth, N. J. • Hartford, Conn. • Beloit, Wis. Tucumcari, New Mexico • Oklahoma City, Okla. • Tulsa, Okla. Hato Rey, P. R. • Caracas, Venezuela



TNEMEC PRIMERS KILL RUST!

THE first step in preserving steel with paint is applying the prime coat. Its primary job is to prevent and kill rust action. TNEMEC 99 Metal Primer does just that, by creating a neutral condition on steel surfaces, changing active rust and corrosive agents into an inactive neutral compound.

The second step is applying the finish coat that will provide protection against the specific exposure hazards involved.

SEWAGE ATMOSPHERE IS CORROSIVE!

. . . and 457 TNEMECOL is your best protection against its disintegrating action. Used as a finish coat over TNEMEC 99 Primer, TNEMECOL forms a tough, flexible film that makes steel surfaces immune to sludge and its gases.

Try this team on your next job—TNEMEC 99 Primer and 457 TNEMECOL—the combination that has whipped the toughest corrosion problems occurring in sewage treatment plants.

Write for your copy of
Painting Specifications for Sewage Treatment Plants

SEE OUR CATALOG IN SWEET'S

MAIL THIS COUPON FOR YOUR COPY OF TNEMEC CATALOG 50

TNEMEC COMPANY, INC.

TNEMEC COMPANY, INC.
135 W. 23rd Ave., North Kansas City, Missouri
Gentlemen:
Send my copy of your Catalog 50 to:

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The correct and positive way to GUARD AGAINST THE DANGERS CAUSED BY INDUSTRIAL WASTES

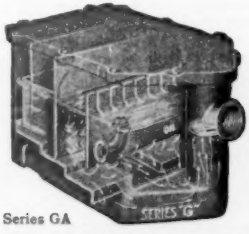
Josam INTERCEPTORS

The handling of industrial wastes has become such a serious problem in many communities that Health and Fire Departments are working together to combat the hazardous and unsanitary conditions, resulting from the discharge of waste materials into sewer lines and public water courses.

Explosive gases, liquids and unsanitary wastes found in sewers and sewage treatment plants today, come from the waste lines of garages, hangars, filling and service stations, repair shops, laundries, dry cleaning plants, machine shops, sheet and plate mills, refineries, stills and other similar plants. The wastes from these establishments contain explosive gases or hazardous elements resulting from decomposition of organic matter, or from the discharge of gasoline or lubricating oils, benzine, naphtha or similar solvents used in manufacturing or servicing.

Serious fires along river banks, and the pollution of water in streams and lakes have been traced by municipalities to the flammable oils and other volatile liquids which have been discharged into these waters. The uncontrolled dumping of greasy wastes from restaurants, schools, and industrial plants has likewise caused pipe lines to fill up, sewers to clog, and sewage treatment to be retarded.

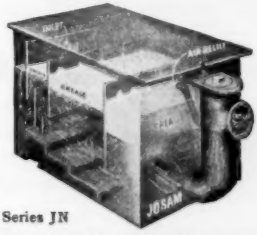
The quickest, easiest and most economical way to provide positive protection against these hazards is to install Josam Interceptors of the approved type and size at all recommended points.



Series GA

Josam OIL INTERCEPTORS

With a Josam Oil Interceptor located at the proper point, dangerous liquids are quickly intercepted from the waste water and are safely drawn off to a point where they can be reclaimed. A dangerous source of fire, explosion and water pollution is completely and positively eliminated. There is a type and size with a guarantee of 95% efficiency for every need. Write for free copy of Manual "E" on Oil Interception.



Series JN

Josam GREASE INTERCEPTORS

Josam Grease Interceptors guard against the hazard caused by grease wastes. They intercept grease from waste water regardless of water temperature . . . evacuate solids . . . keep pipe lines clear. Separated grease is easily removed. All Josam Cast Iron Interceptors carry the "Seal of Approval" of the Plumbing Drainage Institute with a rating of 90% or more grease retention capacity. There is a type for every requirement. Write for free copy of manual "B" on "Grease Interception."

JOSAM MANUFACTURING COMPANY

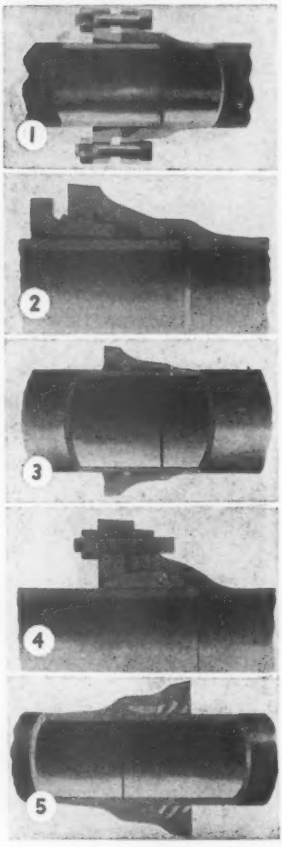
Dept. 51 **MICHIGAN CITY, INDIANA**

Representatives in All Principal Cities

MONO-CAST CENTRIFUGAL PIPE

WITH JOINTS FOR EVERY SERVICE CONDITION

Mono-Cast Centrifugal Pipe can be supplied with joints for conveying water, gas, oil, sewage, and other liquids under every service condition. In most cases, these joints can be made up with unskilled labor and without special tools. Among the joints available are:



1. AMERICAN DOUBLE-X PIPE—A standardized *mechanical joint pipe* equipped with stuffing box type of joint having a ring gasket, cast iron gland, and cast iron bolts. Scientifically designed to meet the exacting requirements of low, medium and high-pressure service in handling gas and liquids.

2. SCREW-GLAND PIPE—An all-purpose economical, mechanical joint pipe suitable for water, gas, oil and other fluids, developed in answer to the demand for a rubber packed joint without bolts suitable for normal service and pressure conditions. Screw-Gland Pipe provides for liberal lateral deflection and provision for expansion and contraction of the pipe line without leakage.

3. ROLL-ON JOINT PIPE—Designed as an alternate for bell and spigot pipe for conveyance of water, sewage or similar liquids. It is quickly and easily assembled by unskilled labor and after assembly the joint will easily deflect and remain tight under pressure.

4. MOLOX BALL JOINT PIPE—An exclusive Acipco development, designed for river crossings and other installations requiring excessive joint deflection. It is positively locked against joint separation and remains bottle tight under pressures up to several hundred pounds per square inch at any angle within the range of deflection for which it is designed.

5. STANDARD BELL AND SPIGOT PIPE—Used under normal service conditions, the standard bell and spigot joint will give long and dependable service. The joints of bell and spigot pipe are made up of lead and jute, cement, or any other special jointing material customer may desire to use. It is supplied in diameters 3" through 48" inclusive.

Write for literature, stating the kind of joint in which you are interested. Address the ACIPCO office nearest you.

AMERICAN CAST IRON PIPE COMPANY

BIRMINGHAM 2, ALABAMA

Dallas	Houston	El Paso	Pittsburgh	Kansas City	New York City
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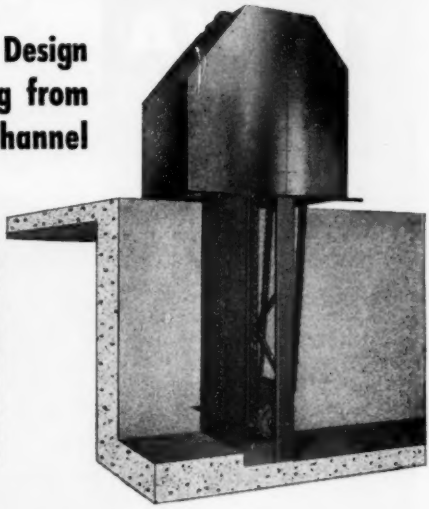
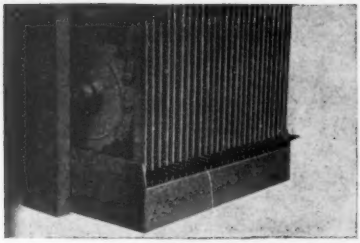
COMPLETELY AUTOMATIC MECHANICALLY CLEANED

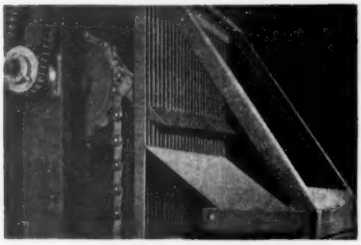
UNIT BAR SCREEN

Exclusive Pivoted Rake Design Assures Positive Raking from Absolute Bottom of Channel





Horizontal position of rake teeth at the beginning of cleaning cycle accomplishes raking from absolute bottom of channel. Gets under and picks up all screenings—does not push them away • Note unobstructed channel approach.



Rake making 45° radial drop to discharge screenings into trough—Note shear pin hub with tool steel shaft and hub inserts for perfect shear action.

THE "AMERICAN" UNIT SCREEN

Completely automatic with a limit switch which stops operation with the rake out of the flow when time control or water level control cycles have been completed • Easily installed as a unit in concrete channels • Total height of unit from mounting floor to motor base is only five feet • The entire above-floor structure is enclosed with stainless steel panels secured by quick opening fasteners to permit easy inspection and access.

Send for Technical Supplement "MS"

See Working Model On Display at The Silver Anniversary Meeting of the Federation of Sewage and Industrial Wastes Associations—New York City—October 6-9, 1952

AMERICAN WELL WORKS

IN OUR 84th YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH • ENGINEERING • MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

whatever your *Control* problems...

IOWA

is ready to meet your every requirement...

IOWA Motor Operated Gate Valve...
Sewage plant influent

IOWA Gate and Check Valves...
Sewage pump discharge

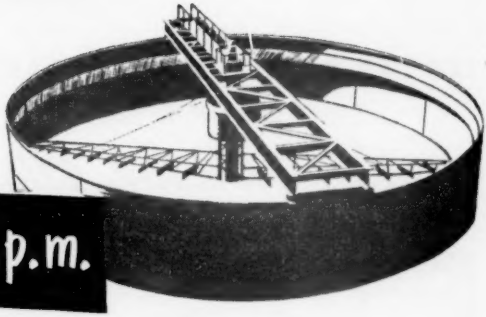
IOWA Manually Operated Sluice Gate...
Settling basin drain

IOWA'S complete line of gate valves, check valves, flap valves, shear gates, mud valves and sluice gates is specially designed for severe and particular operating conditions in sewage disposal plants, sewage pumping stations or wherever sewage flow control is required. Let us help you solve your problems. Specify IOWA products and get the best.

IOWA VALVE COMPANY

201-299 N. Talman Ave., Chicago 80, Ill. • *A Subsidiary of James B. Clow & Sons*

Carter Circular Collectors efficiently remove sludges & solids from liquids having turbidity contents as high as



60,000 p.p.m.

● There is no job too tough for the Carter Circular Collector. In small plants or large, whether the application be water, sewage or industrial waste, this equipment can be depended upon to collect solids continuously and efficiently, from the full radius of the tank, *regardless of sedimentation rate.*

Such performance, under virtually every adverse operating condition has proved to engineers that the Carter Circular Collector is the "backbone" of successful clarification.

specify CARTER for these advantages:

Horizontal or vertical influent offering central subsurface, radial feeding . . . direct mounted vertical speed-reducer combination type drive, with mechanical-electrical overload protection . . . automatic continuous scum removal for full radius of primary tanks . . . positive plow-blade sweeping of tank bottom to central discharge hopper . . . central effluent well and peripheral overflow weir equi-distant at all points from feed entrance.

Write today for free copy of BULLETIN #4906 on Carter's Circular Collectors

R. B. CARTER SALES

207 ATLANTIC STREET, HACKENSACK, NEW JERSEY

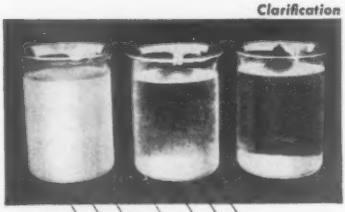
SEWAGE PLANT OPERATORS

For Clarification or Sludge Drying

INVESTIGATE THE ADVANTAGES

IN USING *GENERAL CHEMICAL* "ALUM"

Clarification



Above photograph illustrates effective coagulation and clarification of turbid waste by means of General Chemical Alum.

Clean and easy to handle

Dry feeds well or dissolves readily for solution feeding

Requires only low-cost feeding equipment and minimum attention

Helps sludge digest readily

Speeds sludge drying with minimum odor

Produces clear, low-color effluents

Reduces chlorine consumption in effluent

Economical to use

Sludge Drying

Above: Sludge bed treated with General Chemical Alum to hasten dewatering.

BASIC CHEMICALS

FOR AMERICAN INDUSTRY

Wherever your plant may be—America over—you will find General Chemical "Alum" is always the same high quality . . . always uniform . . . always readily available from coast-to-coast producing and shipping points. To you, that means increased efficiency, stepped-up economy in your clarification and sludge drying operations. So be sure. Get the best; specify General Chemical "Alum"—the *preferred* "Alum."

GENERAL CHEMICAL DIVISION

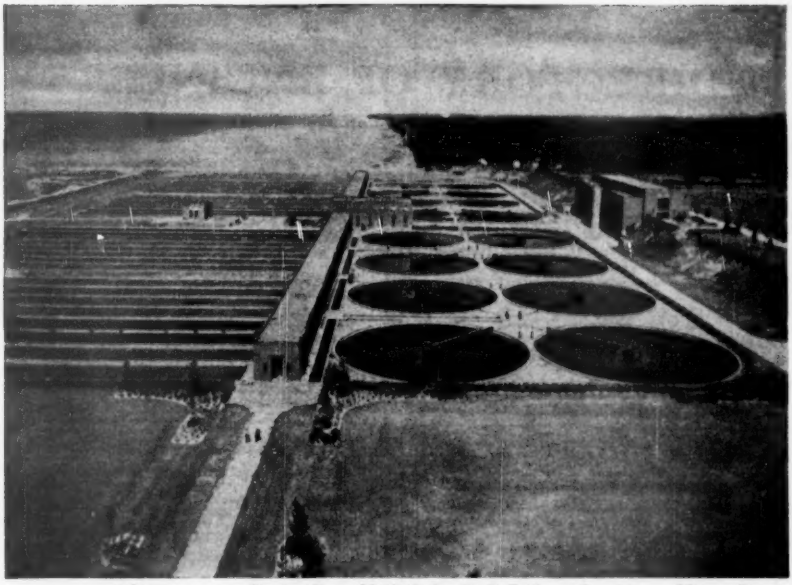
ALLIED CHEMICAL & DYE CORPORATION

40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport Buffalo • Charlotte • Chicago • Cleveland • Denver • Detroit • Houston Jacksonville • Los Angeles • Minneapolis • New York • Philadelphia Pittsburgh • Providence • San Francisco • Seattle • St. Louis • Yakima (Wash.)

In Wisconsin: General Chemical Company, Inc., Milwaukee, Wis.

In Canada: The Nichols Chemical Company, Limited
Montreal • Toronto • Vancouver



Information courtesy Cleveland Dept. of Public Works—Mr. G. E. Flower, Commissioner of Sewage Disposal.

Cleveland's Easterly sewage plant uses ALOXITE diffusers

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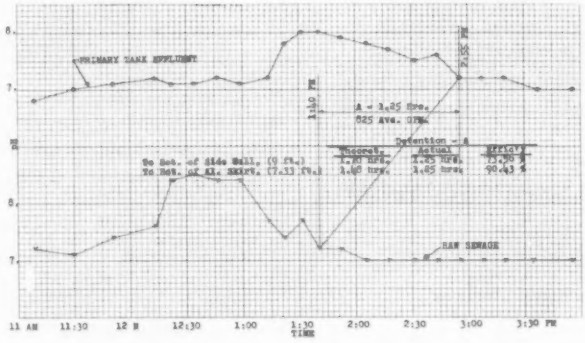

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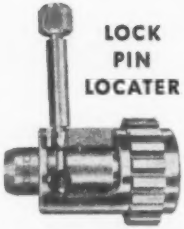

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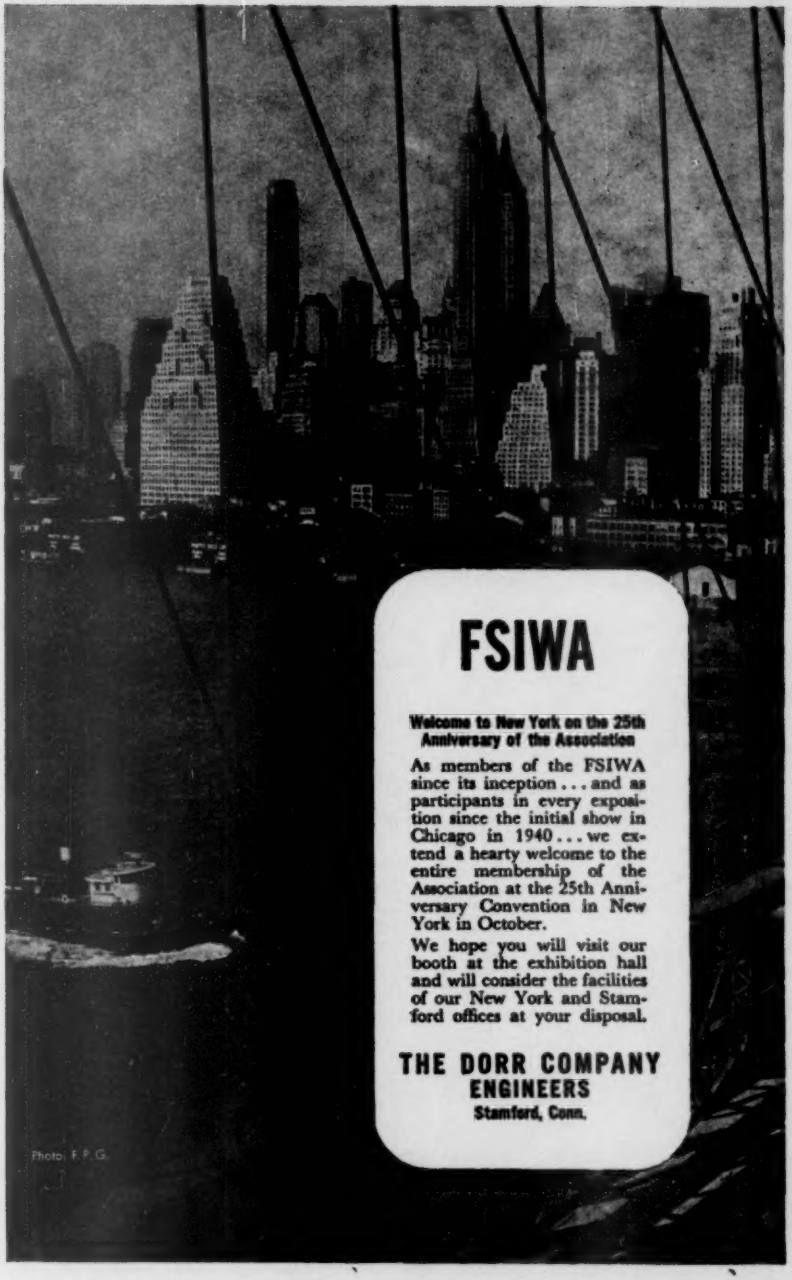
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